Installation and Configuration Manual
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Micro Motion® 3098 Gas Specific Gravity Meter

Micro Motion

EMERSON™
Process Management

Contents

Chapter 1
Introduction

This chapter contains an outline of how the 3098 specific gravity meter works, defines some of the terms commonly used in the manual, and also gives some practical applications for the 3098.

The 3098 specific gravity meter is normally installed in an IP rated enclosure prior to leaving the factory. In some instances however, the 3098 specific gravity meter may be supplied without an enclosure, in which case the environmental and thermal performance of the meter cannot be guaranteed. Warnings are given throughout this manual when the performance of the meter may be affected by this.

For technical details, please refer to the system installer.

The pressure relief valve has been factory set for the unit to conform to the Pressure Equipment Directive. Under no circumstances should this setting be changed.

For further information, contact the factory using the details on the back page of this manual.

1.1 Safety guidelines

Handle the 3098 specific gravity meter with great care.

- Do not drop the meter.
- Do not use gases incompatible with materials of construction.
- Do not operate the meter above its rated pressure.
- Do not expose the meter to excessive vibration (> 0.5 g continuous).
- Ensure all electrical safety requirements are applied.
- Ensure good ventilation around the meter / cabinet to prevent gas build up in the unlikely event of a leak.
- Ensure meter is not transported when it contains hazardous substances. This includes fluids that may have leaked into, and are still contained, within the case.
- Ensure that a Balston coalescing filter is fitted into the gas supply line to the 3098 meter. Either a type 85 or a 91S6 (as supplied) MUST be fitted to comply with ATEX/IECEx approval requirements.
- To return a meter, refer to Appendix C for more information on the Micro Motion return policy.

Safety messages are provided throughout this manual to protect personnel and equipment. Read each safety message carefully before proceeding to the next step.

1.2 Specific gravity measurement

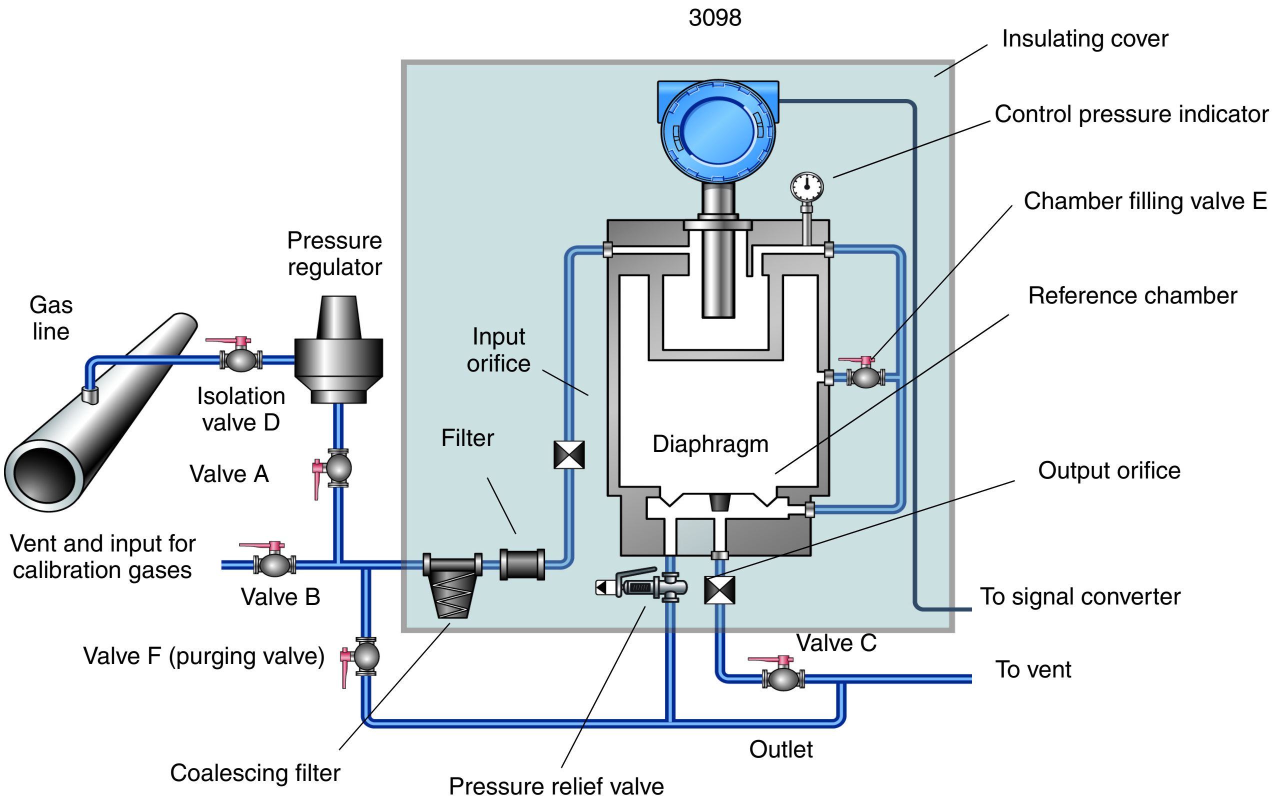
Most major gas flow metering systems require the metered quantity to be presented in heat or standard volume units. To achieve this requirement, it is often necessary to make continuous and accurate measurements of specific gravity. Specific gravity can be evaluated by relating the molecular weight of the gas (or gas mixture) to that of the molecular weight of air, or by evaluating the relative density of the gas (or gas mixture) and compensating the result for the Boyle's Law deviation on both the gas (or gas mixture) and the air.

The 3098 specific gravity meter adopts a combination of these two methods, where, by measuring the density of the gas under controlled conditions, the value of density obtained is directly related to the molecular weight of the gas, and thus to its specific gravity.

Figure 1-1 View of the 3098 specific gravity meter installed in a typical enclosure

1.3 Functional description

Figure 1-2 Schematic diagram of a typical 3098 specific gravity measuring system



The 3098 specific gravity meter consists of a vibrating cylinder gas density meter surrounded by a gas reference chamber, which helps to achieve good thermal equilibrium. The gas reference chamber has a fixed volume that is initially pressurized with the actual line gas. It is then sealed by closing the reference chamber filling valve, thus retaining a fixed measure and quantity of gas, now known as the reference gas.

Note: Once the chamber has been filled, do not open the reference chamber filling valve again.

The sample gas enters the instrument at the enclosure side and passes through a filter, followed by a pressure-reducing orifice. The sample gas is then fed through input pipework so that it enters the gas density meter at the equilibrium temperature of the unit. The gas then flows down to a pressure control valve chamber.

The pressure of the reference gas acts on the separator diaphragm and forces the line gas pressure to rise until the pressures on both sides are equal, thus the gas pressures within the gas density meter and the reference chamber are equal.

As the ambient temperature changes, the pressure of the fixed volume of reference gas will change as defined by the Gas Laws. This change in pressure will affect the sample gas pressure within the gas density meter such that the temperature and pressure changes are self-compensating.

If the sample gas pressure rises above that of the reference chamber pressure, the pressure control valve opens to vent the excess gas via an outlet orifice in the enclosure side, so that the sample gas pressure is reduced to equal the reference gas pressure. For gas to flow it is necessary that the supply pressure is greater than the reference pressure, which in turn must be greater than the vent pressure. (Typically the line pressure must be between 15% and 25% above that of the reference chamber pressure).

Note: The principles of operation that describe this operation are given in Appendix B.

A pressure gauge is fitted in order to monitor the pressure within the gas density meter. This is desirable when charging the reference chamber and also for general maintenance.

Electrical connections to the 3098 specific gravity meter are taken through the cable gland in the enclosure side and then into the density meter's electronics housing.

When the enclosure is sealed, the complete instrument is insulated so that rapid changes in ambient temperature will not upset the temperature equilibrium of the unit and produce thermal shock errors.

Note: The 3098 specific gravity meter may have been supplied without an enclosure – see Safety guidelines on page 1.

1.3.1 Meter sensing element

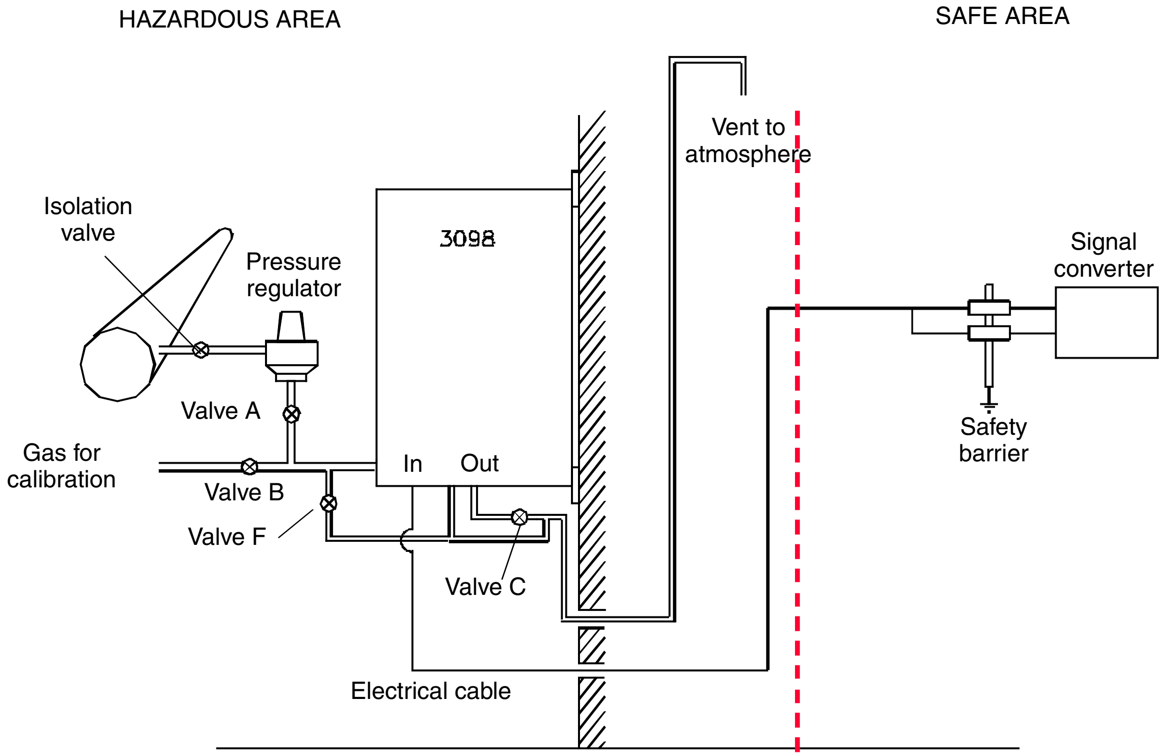
The gas density meter consists of a thin metal cylinder which is activated so that it vibrates in a hoop mode at its natural frequency. The gas is passed over the inner and outer surfaces of the cylinder and is thus in contact with the vibrating walls. The mass of gas which vibrates with the cylinder depends upon the gas density and, since increasing the vibrating mass decreases the natural frequency of vibration, the gas density for any particular frequency of vibration can be determined.

A solid state amplifier, magnetically coupled to the sensing element, maintains the conditions of vibration and also provides the output signal.

1.3.2 Installation

The 3098 specific gravity meter has been designed to be installed mounted to a wall (wall mounted), a typical installation set-up being given in Figure 1-3 below.

Figure 1-3 **Typical 3098 specific gravity measuring system**



1.4 Definition of terms

1.4.1 Specific gravity

Specific gravity (G) is the ratio of the molecular weight of a gas (or gas mixture) to that of the molecular weight of dry air; the molecular weight of dry air is normally assumed to be 28.96469 (see Table 1-1).

for example

$$G = \frac{M_G}{M_A}$$

where M_G = molecular weight of gas (or gas mixture)

and M_A = molecular weight of dry air

1.4.2 Standard (base or normal) density

Standard (base or normal) density (ρ_s) is the absolute density of a gas at standard (base or normal) conditions of temperature and pressure and is commonly used for standard volumne flow determination from mass flow measurement.

for example

$$\rho_s = \frac{pM}{ZRT}$$

where

p = absolute pressure (bars)

T = absolute temperature (degrees Kelvin)

M = molecular weight

Z = supercompressibility factor

R = gas constant (taken as 0.0831434)

1.4.3 Relative density

Relative density (ρ_r) is the ratio of the weight of a volume of gas (or gas mixture) to the weight of an equal volume of dry air (see Table 1-1), where the weights of both gas (or gas mixture) and air are taken under identical conditions of temperature and pressure.

Note: Except for the effects of Boyle's Law deviation upon both the gas (or gas mixture) and the air, G and ρr are synonymous.

for example

$$G = \frac{M_G}{M_A}$$

$$= \frac{\rho_G Z_G}{\rho_A Z_A}$$

$$= \rho_r \cdot \frac{Z_G}{Z_A}$$

where

ρ_G = density of the gas or gas mixture

ρ_A = density of air

Z_G = supercompressibility factor of the gas or gas mixture

Z_A = supercompressiblity factor of air

The relative density of mixed hydrocarbon gases at 1 bar (14.50377 lb/in^2) absolute and 15.56°C (60°F) by empirical equation is:

$$\rho_r = 0.995899G + 0.010096G^2$$

1.5 Physical properties of gas compounds

Table 1-1 Physical properties of gas compounds

Compound	Formula	Molecular Weight(1)	Specific Gravity(2)
Hydrogen	H_2	2.01594	0.069600
Helium	He	4.00260	0.138189
Water Vapour	H_2O	18.01534	0.621976
Nitrogen	N_2	28.01340	0.967157
Carbon Monoxide	CO	28.01055	0.967058
Oxygen	O_2	31.99880	1.104752
Argon	Ar	39.94800	1.379197
Air(3)	–	28.96469	1.000000
Hydrogen Sulphide	H_2S	34.07994	1.176603
Methane	CH_4	16.04303	0.553882
Ethane	C_2H_6	30.07012	1.038165
Propane	C_3H_8	44.09721	1.5522447
i-Butane	C_4H_{10}	58.12430	2.006730
n-Butane	C_4H_{10}	58.12430	2.006730
i-Pentane	C_5H_{12}	72.15139	2.491012
n-Pentane	C_5H_{12}	72.15139	2.491012
Hexane	C_6H_{14}	86.17848	2.975294
Heptane	C_7H_{16}	100.20557	3.459577
Octane	C_8H_{18}	114.23266	3.943859

(1) Based upon 1961 atomic weights, referred to Carbon-12 Isotope (12 AMU), recommended by the International Commission of Atomic Weights and the International Union of Pure and Applied Chemistry.
(2) Perfect gas specific gravity represents the ratio of molecular weight of compounds to the molecular weight of air.
(3) Molecular weight of air based upon components of atmospheric air given in Handbook of Chemistry & Physics, 53rd Edition (1972–1973). Value of 28.96469 differs from figure 28.966 provided by NBS Circular 564 due to minute differences in component content and changes in atomic weights of the elements given in 1961 (NBS value based upon 1959 atomic weights).

1.6 Applications

The following are typical applications where specific gravity measurement is an essential parameter.

1.6.1 Supplementary gas supply

This system is used to top up normal supplies during peak periods. Specific gravity monitoring of a propane/air mixture, for example, enables accurate control to be exercised over the ratio of the mixture, therefore ensuring that the correct burning characteristic/calorific value is maintained.

1.6.2 Wobbe index measurement

The burning characteristic of a gas must be well established for efficient combustion and to ensure that no flame lift or flame light-back occurs on a particular burner. Three criteria are used to establish this characteristic; calorific value, specific gravity and flame speed. The calorific value and specific gravity are often combined to form the Wobbe Number:

Wobbe number $= \frac{CV}{\sqrt{G}}$

where CV = calorific value

G = specific gravity

1.6.3 Consumer gas costing

This major application has already been described in the introduction, mass to base volume unit conversion, and may be further illustrated by the following equations:

Base unit volume $= \frac{\text{Mass flow}}{\text{Base density}}$

for example

$$Vs = \frac{M}{\rho_s}$$

$$= \frac{M}{G\frac{P_A Z_A}{Z_G}}$$

Chapter 2
Installation Procedure

2.1 Installation procedure

The procedure for installing the 3098 involves the following steps:

1. Check all components are present (Section 2.2).
2. Position and fix the 3098 enclosure (Section 2.3).
3. Connect the gas supply line (Section 2.3.2).
4. Fit the supplied coalescing filter into the gas supply line in accordance with manufacturer's instructions (Section 2.3.3) .
5. Make electrical connections (Section 2.4 and Chapter 3).
6. Select a reference pressure (Section 2.5).
7. Purge cycle and calibrate the 3098 (Section 2.6).

2.2 Contents

The following items should be enclosed with the 3098 unit:

- 3098 specific gravity meter
- Labeled enclosure
- Enclosure mounting feet
- Enclosure mounting feet instructions
- 3098 Installation and Configuration manual (MMI-20014120)
- Safety instructions (CE-marked units only)
- Accessories kit
- Temperature Coefficient Calibration certificate

Note: Check that all the above items are present. If not, then contact your supplier immediately. (Be aware that the 3098 may have been supplied without an enclosure.)

2.3 Installing the 3098 enclosure

The following installation instructions apply only to meters supplied with an enclosure (see Safety guidelines on page 1). In all other cases, please refer to the system installer.

2.3.1 Important precautions

Take care to observe the precautions listed in Safety guidelines on page 1.

The 3098 specific gravity meter is contained inside an IP-rated enclosure (which provides thermal insulation) and a mounting system (consisting of a bracket and feet) to fix the unit in place. While this structure is designed to minimize damage due to shocks, the box and unit must not be dropped. Dropping the 3098 specific gravity meter either inside or outside its enclosure will damage the meter.

Contained inside the enclosure are four box feet which, when attached to a vertical wall will hold the housing. A set of instructions on how to attach these feet is included inside the box. Enclosure dimensions are in Section 2.7.

2.3.2 Connections

There are four connections that need to be made to the 3098 specific gravity meter: three gas pipeline connections and one electrical connection through an IP-rated cable gland. The gas pipeline connections take the form of ¼" Swagelok bulkhead fittings, and are used for the gas input, gas output and pressure relief lines.

Each connection is labelled.

Connecting the gas input line to the wrong bulkhead fitting might result in damage.

A gas density meter is used as the measuring instrument in the 3098 specific gravity meter and needs to be connected inside the enclosure. All wiring should be connected through the cable gland to maintain the enclosure's overall protection to dust and water ingress.

At all stages during calibration and operation, the 3098 specific gravity meter is designed to function with the enclosure sealed. This allows the unit to operate in the condition of thermal equilibrium, which is essential for accurate measurement.

2.3.3 Coalescing filter

Ensure that the coalescing filter (as supplied) is fitted into the gas supply line to the 3098 meter. This MUST be done in order to comply with the ATEX/IECEx approval requirements.

2.4 Electrical connections and safety barriers / galvanic isolators

When the 3098 specific gravity meter is mounted in a hazardous area, the electrical connections to the meter must conform to stringent conditions. For electrical connections between the meter and its associated flow computer/signal converter, for ATEX/IECEx installations see the ATEX/IECEx Safety Instructions booklet (available at www.micromotion.com) and for CSA installations see Appendix D.

Electrical cable connection to the 3098 specific gravity meter is made to the terminal block inside the resonator electronics housing (for example, inside the enclosure). Poor connection to the terminals will prevent correct operation but will not damage the unit – provided that safety barriers or galvanic isolators are included in the circuit for hazardous areas or the maximum power supply does not exceed the 33 V maximum limit (as described in Chapter 3).

The power supplied to the meter terminals should be in the range of 15.5 to 33 Vdc with the average current drawn by the unit being < 20 mA. If the current consumption exceeds this value, the polarity of the connections should be checked.

A full description of how to connect the 3098 specific gravity meter to a signal converter/flow computer is given in Chapter 3.

2.5 Reference chamber pressure determination

Once the 3098 specific gravity meter has been placed in its fixture and all relevant pipework and electrical connections made, the reference chamber pressure needs to be determined.

The gas type and reference chamber pressure define the ‘controlled condition’ at which the unit allows gas to flow and establishes a direct relationship between density and the specific gravity of the sample gas.

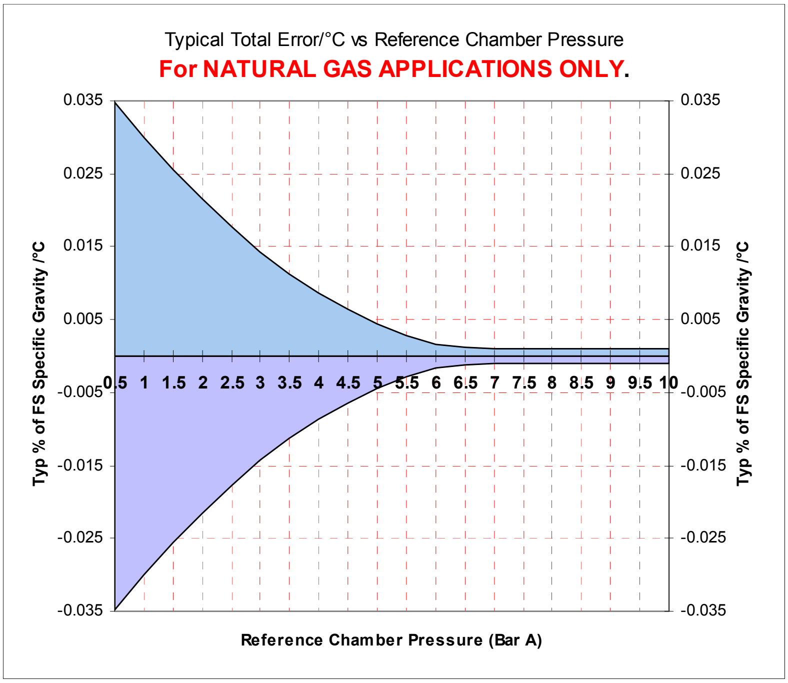
The choice of reference chamber gas pressure is dependent upon three factors:

- The span of specific gravity to be measured
- The expected change in sample gas supercompressibility, Z
- The accuracy required

The graph below gives an indication of the typical errors associated with using different reference chamber pressures for natural gas with a reasonably constant specific gravity (in the range of 0.55 – 0.8). This is typical for natural gas metering market, where the gas is available at a line pressure of 7 Bar abs.

As can be seen, below 7 Bar abs, the total error begins to increase; using a higher reference pressure will not improve accuracy, but may encourage gas leakage. Therefore, for the conditions specified, 7 Bar is the recommended pressure.

Figure 2-1 Typical total error/°C versus reference chamber pressure



This graph should only be used for natural gas applications, and.gives typical errors seen on the 3098 specific gravity meter if it is not used at the recommended reference chamber pressure.

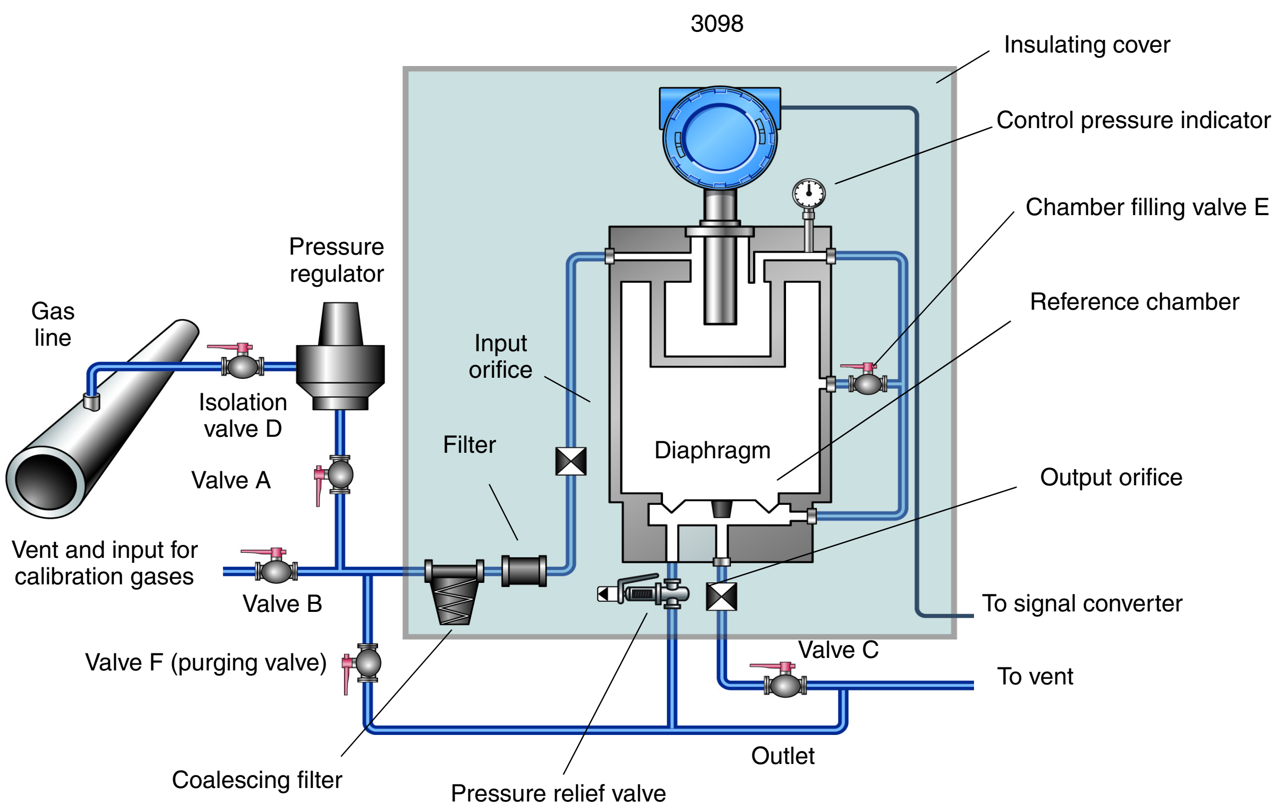
If the span of specific gravity or change in supercompressibility, Z, is large, and the gas is not a methane/nitrogen mix, then the best reference chamber pressure can still be determined. The calculation for doing this is explained in Chapter 4.

Once the desired reference pressure has been found, the 3098 specific gravity meter can now be purge cycled and then calibrated.

2.6 Set-up procedure – purge cycling and calibration

The pressure relief valve has been factory set for the unit to conform to the Pressure Equipment Directive. Under no circumstances should this setting be changed. For further information, contact the factory using the details on the back page.

Figure 2-2 **Schematic diagram of a typical 3098 specific gravity measuring system**



The procedure for purging and calibrating the 3098 specific gravity meter is given below (see Figure 2-2 for reference):

1. Ensure isolation valve D is closed.
2. Ensure valve A is closed.
3. Ensure valve B is closed.
4. Ensure valve F is closed.
5. Open valve C.
6. Open chamber filling valve E.
7. Set the pressure regulator to the required value – for example, the actual working pressure of the system.
8. Open isolation valve D.
9. Open valve A and allow gas to flow for 3 minutes.

Purge cycling

10. Close valve C.
11. When Control Pressure Indicator is at the desired value, shut valve A and open valve F. Allow the gas to vent to atmospheric pressure.
12. Close valve F and open valve A.
13. When Control Pressure Indicator is at the desired value, shut valve A and open valve F. Allow the gas to vent to atmospheric pressure.

    Steps 12 and 13 define the purging cycle required for setting up the reference chamber gas in the 3098 specific gravity meter. The number of times that this procedure should be repeated depends upon the gas regulator pressure used and is defined by:

$$\text{Number of purge cycles} = \left[\frac{3 \times 7}{\text{max regulator pressure}} \right]$$

14. Once the required number of cycles has been performed, close valve F and open valve A.
15. When the desired gas pressure inside the chamber has been reached (as shown by the Control Pressure Indicator) shut the chamber valve.

DO NOT open the chamber valve again. The gas now inside the 3098 chamber is the line reference gas.

3098 specific gravity meter calibration using two known gases

16. Close valve A.
17. Connect the first calibration gas bottle to the pipework and set the pressure to be typically 25% above that inside the reference chamber.
18. Open valve B.
19. Ensure valve C is open and allow gas to flow until the time period as measured by the signal converter/flow computer is stable to ±1 ns or better (the typical stability will be better than this). [For the required electrical connections see Chapter 3]
20. Note this time period (τ_1) together with the certified SG from the bottle of gas (SG_1).
21. Shut valve B.
22. Replace the first calibration gas bottle with the second calibration gas bottle.
23. Set pressure to typically 25% above that inside the reference chamber and open valve B.
24. Allow gas to flow until the time period shown by the meter is stable to ±1 ns or better.
25. Note this time period (τ_2) and the certified SG from the bottle of gas (SG_2).
26. Apply these noted numbers into equations (1) and (2) below:

$$K_2 = \left[\frac{SG_1 - SG_2}{(\tau_1)^2 - (\tau_2)^2} \right] \qquad (1)$$

$$K_0 = SG_1 - K_2(\tau_1)^2 \qquad (2)$$

You can enter this information directly into the Calibration Certificate example in Section 4.4. For an online version of this certificate, download the Calibration Certificate Excel file at www.micromotion.com (located on the 3098 products page) or access the calcert.xls file on the floppy disk shipped with the product.

27. Shut valve B and disconnect the second calibration gas bottle from pipework.
28. Open the isolation valve D.
29. Open valve A.

If the application is running with a reference pressure less than 45.5 psi (3 Bar A), the maximum flow rate that can be used for correct operation is 50 cc/s. A full explanation of this effect is given in Chapter 4.

The unit should now give a live reading of the measured gas SG. If the unit does not output a sensible reading, certain checks can be made. These checks are summarized in Chapter 5.

If optimum SG accuracy is required, the optimization method described in Appendix A – which compensates for errors due to gas velocity of sound, compressibility and temperature coefficient – should be used.

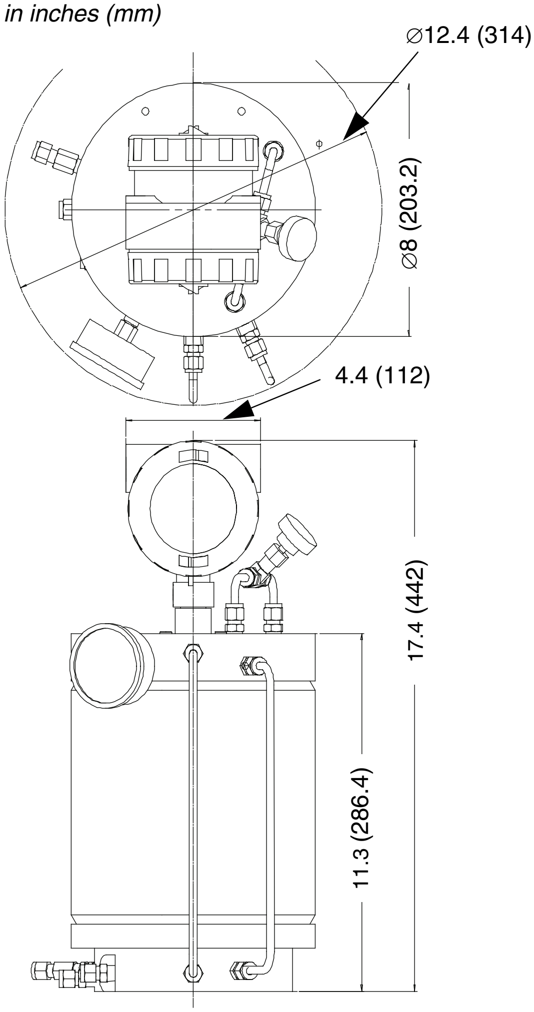
For optimum accuracy, the time period (τ) must be resolved to ±0.1 ns. This can be achieved using 7950/7951 signal converters and flow computers set to a cycle time of 10 s.

2.7 Outline dimensional drawings

Figure 2-3 shows a 3098 specific gravity meter without an enclosure. For dimensions of small and large enclosures, see Figure 2-4 and Figure 2-5.

Figure 2-3 3098 specific gravity meter without an enclosure

Dimensions in inches (mm)



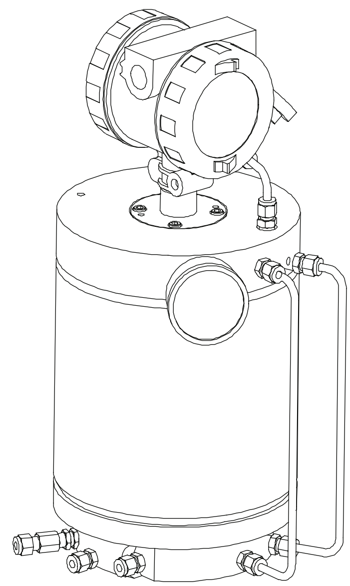


Figure 2-4 **3098 specific gravity meter with a small enclosure**

Dimensions in inches (mm)

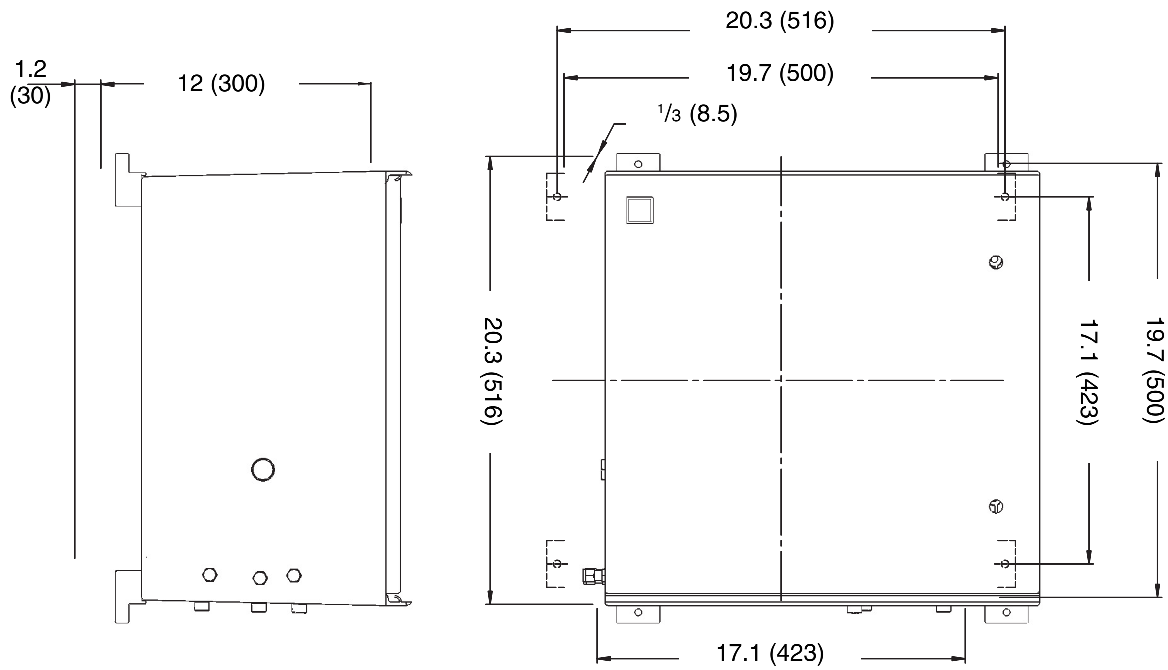
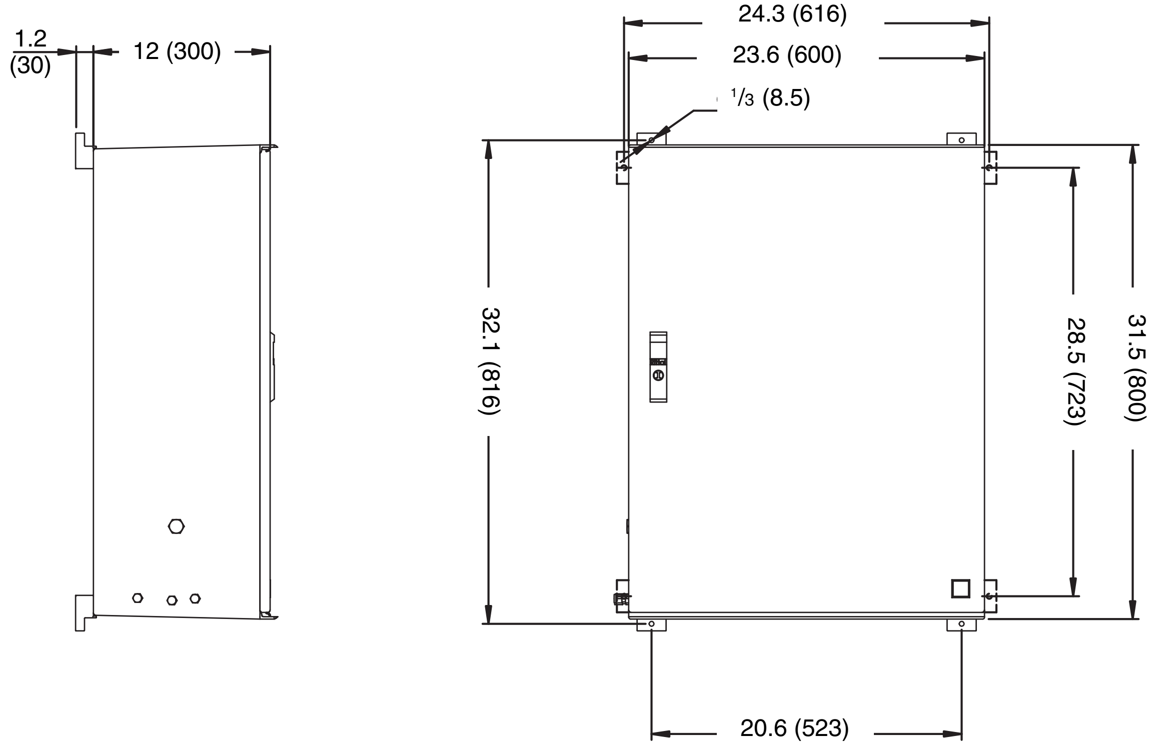


Figure 2-5 3098 specific gravity meter with a large enclosure

Dimensions in inches (mm)



Chapter 3
Electrical Connections

This chapter contains details and wiring diagrams for connecting the 3098 specific gravity meter to 7950/51 signal converters and flow computers, and more generally to other equipment in both hazardous and non-hazardous situations.

3.1 Introduction

The electrical connections to the 3098 specific gravity meter are made to the gas density meter held inside the enclosure. When installed in hazardous areas, connections between the meter and the power supply/readout equipment must be completed through zener safety barriers [or galvanic isolators]. The electrical cable enters the enclosure (if supplied, see Safety guidelines on page 1) through a cable gland assembly and then passes into the amplifier housing.

The meter terminal layout is shown in Figure 3-1.

The amplifier housing has two chambers. The one nearest the cable gland axis contains the terminals for connection to the meter/signal processing instrument. The other chamber contains the maintaining amplifier unit. The amplifier board is encapsulated in a circular plastic container, with the complete module secured by a keyway and a centrally positioned clamping screw. Behind the amplifier there is an interconnect terminal board which links the sensor to the maintaining amplifier, and the amplifier to the user connect board (see Figure 3-2).

Figure 3-1 Main terminal board connections

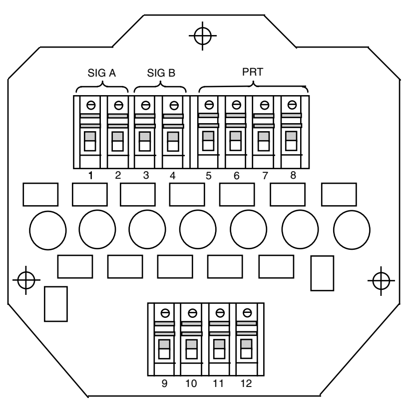
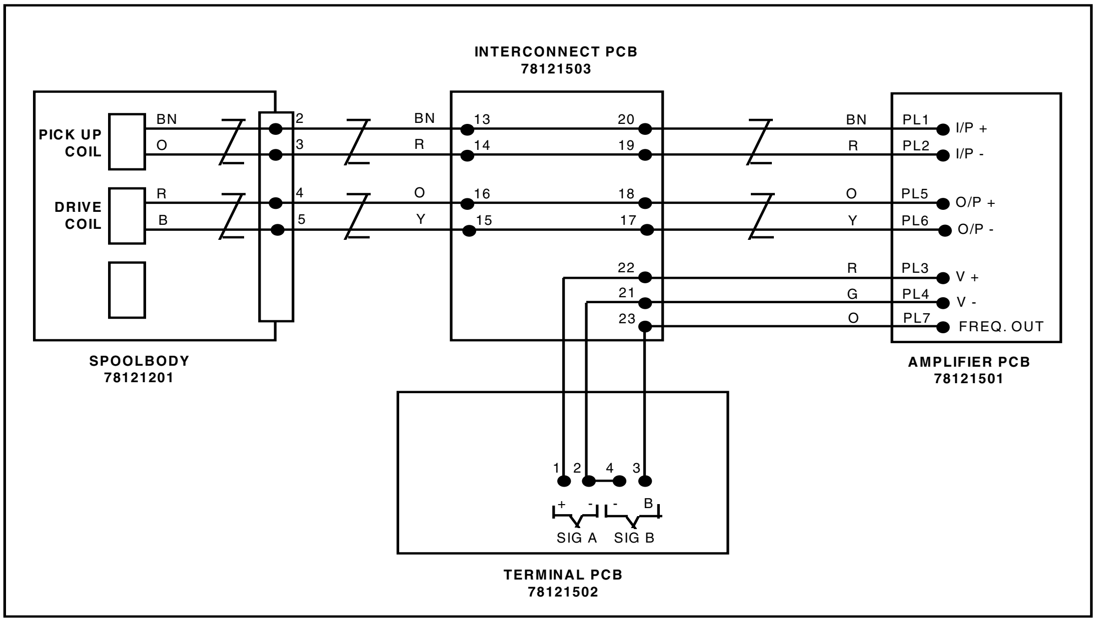


Figure 3-2 **Interconnection diagram**



3.2 EMC cabling and earthing

To meet the EC Directive for EMC (Electromagnetic Compatibility), it is recommended that the meter be connected using a suitable instrumentation cable and earthed through the meter body and pipework.

The instrumentation cable should have an individual screen, foil, or braid over each twisted pair and an overall screen to cover all cores. Where permissible, the overall screen should be connected to earth at both ends (360° bonded at both ends). The inner individual screen should be connected at only one end, the controller end (for example, signal converter end).

Note: For intrinsic safety, termination of the inner individual screen(s) to earth in the hazardous area is not generally permitted.

Note: Use suitable cables that meet BS5308 multi-pair instrumentation Types 1 or 2.

3.3 Certificate conditions for hazardous areas

For details of hazardous area installations, see the ATEX/IECEx Safety Instructions booklet (available at www.micromotion.com) for ATEX/IECEx installations and see Appendix D for CSA installations.

The 3098 specific gravity meter can be electrically connected in either a 2-wire or 3-wire configuration. A schematic block diagram of these two types is given in Figure 3-3 and Figure 3-4.

Figure 3-3 Schematic block diagram of meter circuit (2-wire system)

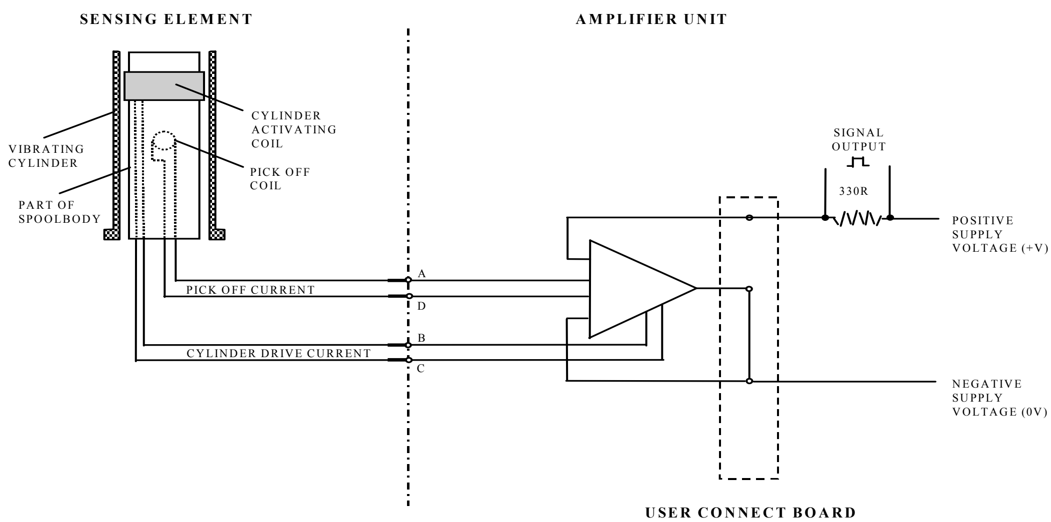
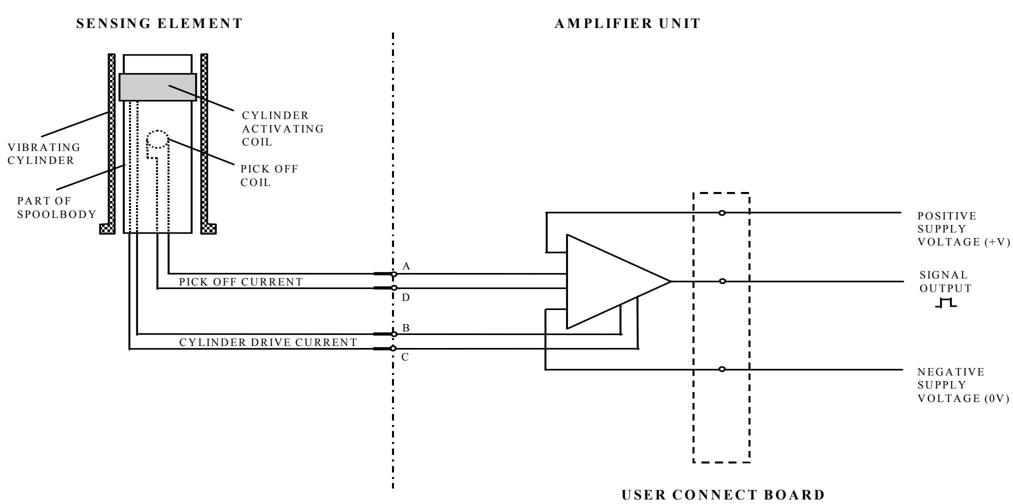


Figure 3-4 Schematic block diagram of meter circuit (3-wire system)



3.4 Use with signal converters and flow computers

The meter can be operated in two general environments, either in safe areas or in hazardous areas. When used in hazardous areas, safety barriers or galvanic isolators must be placed between the meter and the signal converter/flow computer.

When operating in a safe area with a 3-wire system, the line resistance between meter and signal converter must be greater than 40 ohms. This can be achieved by placing a suitable resistor in the line or by using the inherent resistance of the cable used (if the resistance per km and length of cable used is sufficient).

Given these conditions, we recommend that the maximum cable length between the 3098 specific gravity meter and signal converter – assuming a BS5308 standard cable – is 2 km.

When the 3098 specific gravity meter is installed in a hazardous area, see the ATEX/IECEx Safety Instructions booklet (available at www.micromotion.com) for ATEX/IECEx installations and see Appendix D for CSA installations.

For the purposes of clarity, all wiring diagrams describing a safe area setup using the 3-wire system have had a 40-ohm resistor placed into the +24 V power supply line.

3.5 System connections (7950/7951)

The density and power connections to the 3098 specific gravity meter in safe and hazardous areas are shown in the following diagrams:

3.5.1 7950 2-wire configuration

Figure 3-5 **7950 signal converter and gas specific gravity 2-wire system (safe area)**

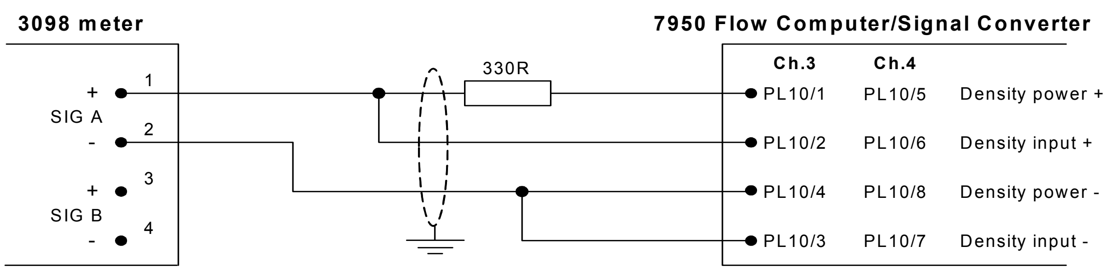


Figure 3-6 **7950 signal converter and gas specific gravity 2-wire system with shunt-diode safety barrier (hazardous area)**

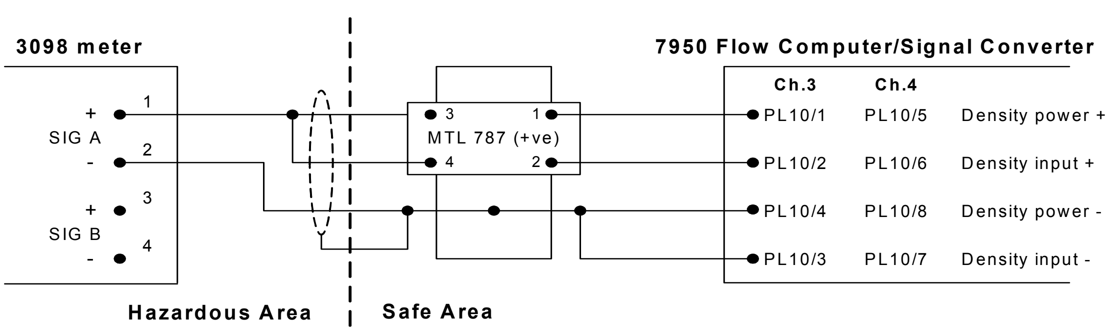
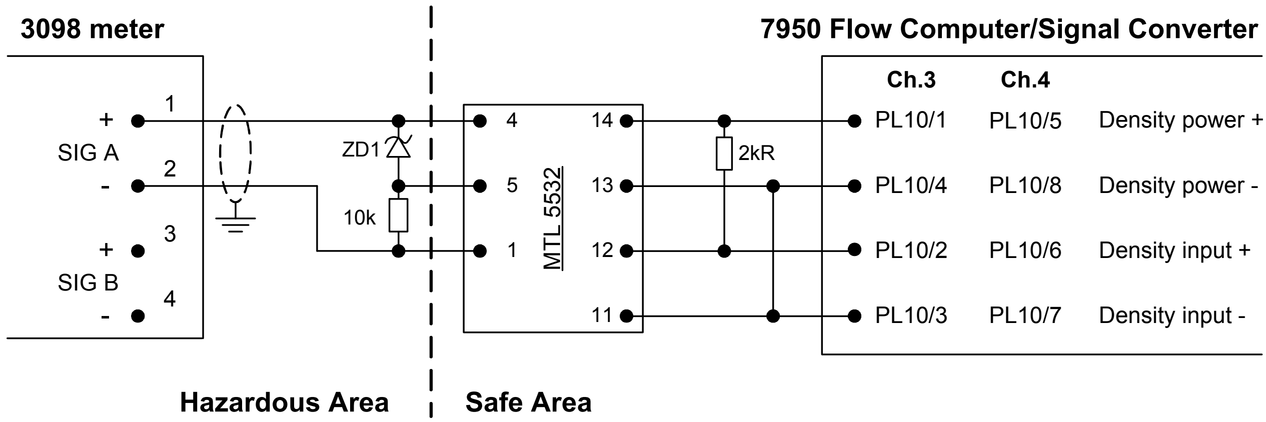


Figure 3-7 **7950 signal converter and gas specific gravity 2-wire system with galvanic isolator (hazardous area)**



Barrier trip level switch settings	Zener voltage
12V	6.2V
6V	13V
3V	16V

Note: When the ATEX/IECEx-approved specific gravity meter is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

3.5.2 7950 3-wire configuration

Figure 3-8 **7950 signal converter and gas specific gravity 3-wire system (safe area)**

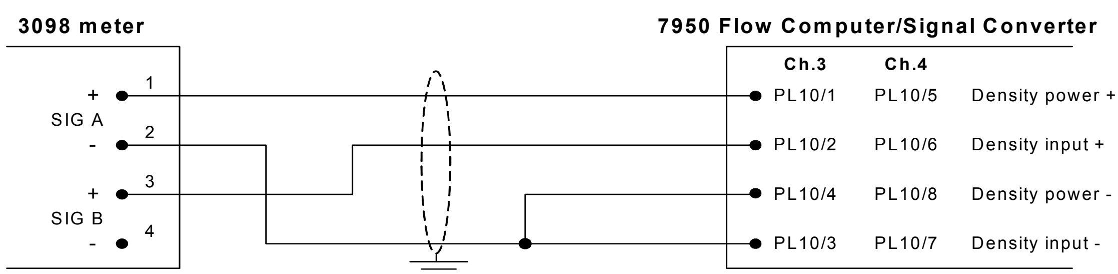


Figure 3-9 7950 signal converter and gas specific gravity 3-wire system with shunt-diode safety barrier (hazardous area)

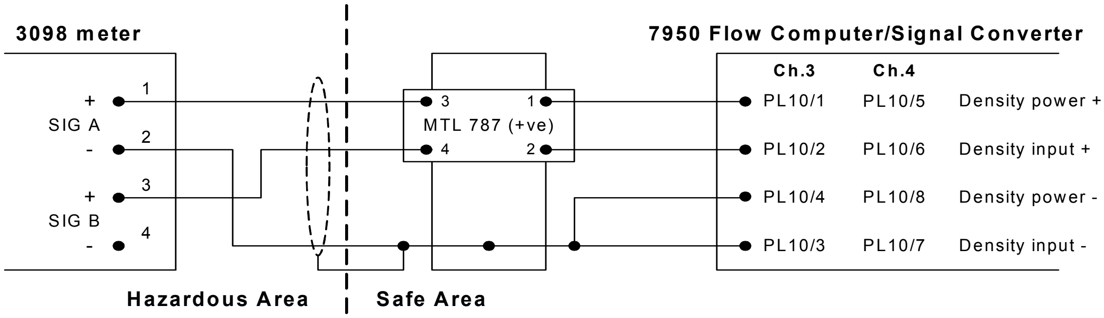
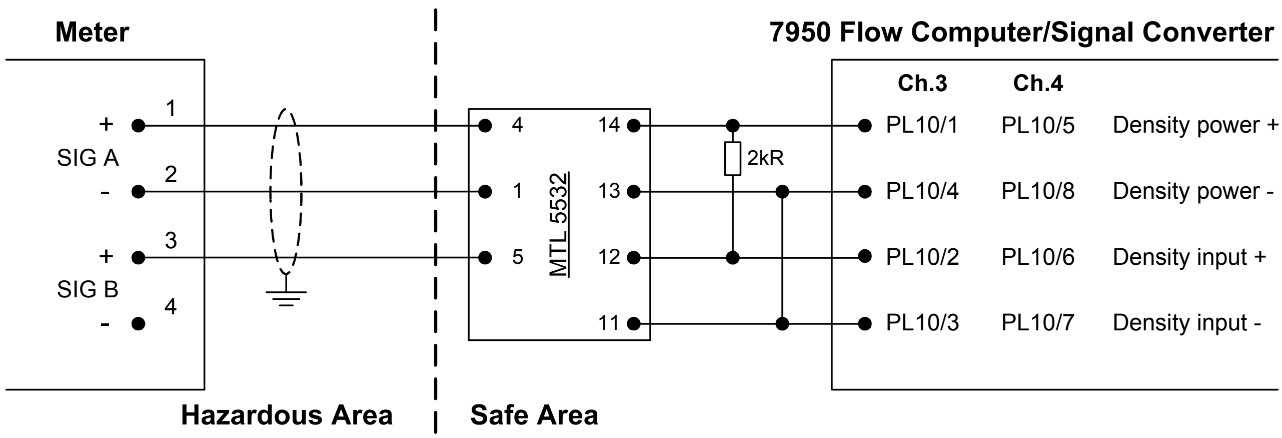


Figure 3-10 7950 signal converter and gas specific gravity 3-wire system with galvanic isolator (hazardous area)



Note: The barrier trip level switch should be set to 3 volts.

Note: When the ATEX/IECEx-approved specific gravity meter is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

3.5.3 7951 2-wire configuration

Figure 3-11 7951 flow computer/7951 signal converter gas specific gravity 2-wire system (safe area)

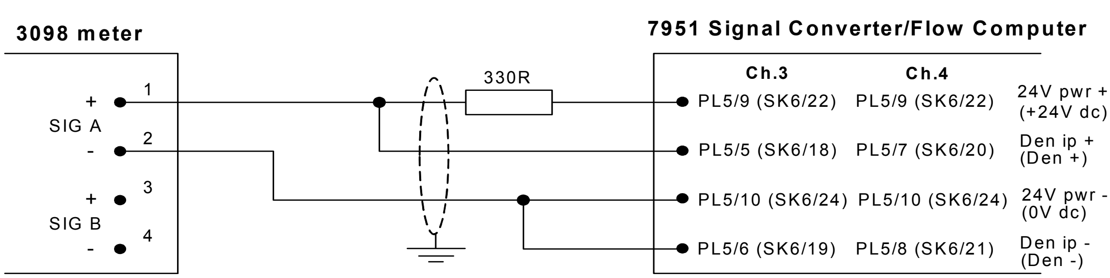


Figure 3-12 7951 flow computer/7951 signal converter gas specific gravity 2-wire system with shunt-diode safety barrier (hazardous area)

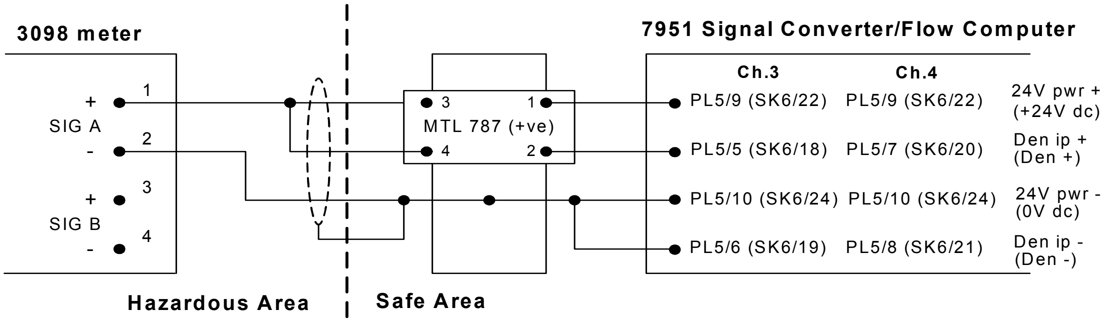
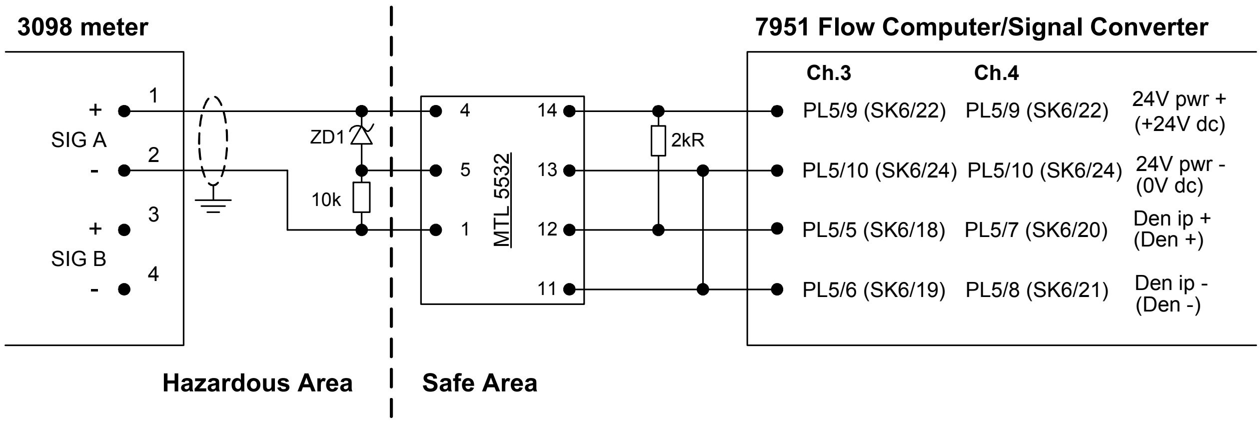


Figure 3-13 7951 flow computer/7951 signal converter gas specific gravity 2-wire system with galvanic isolator (hazardous area)



Barrier trip level switch settings	Zener voltage
12V	6.2V
6V	13V
3V	16V

Note: When the ATEX/IECEx-approved specific gravity meter is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

3.5.4 7951 3-wire configuration

Figure 3-14 7951 flow computer/7951 signal converter gas specific gravity 3-wire system (safe area)

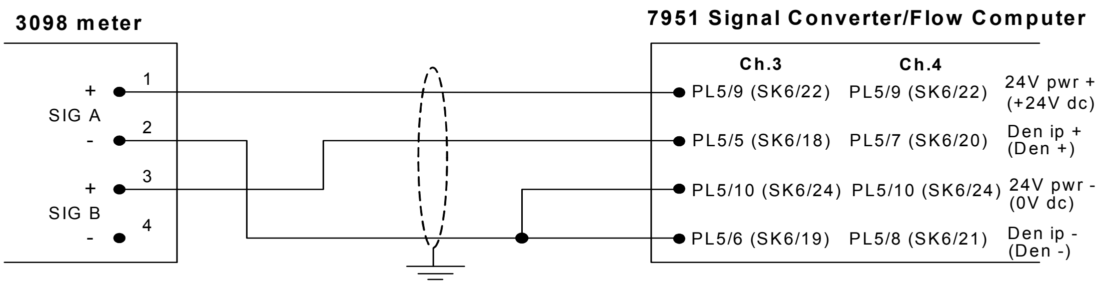


Figure 3-15 7951 flow computer/7951 signal converter gas specific gravity 3-wire system with shunt-diode safety barrier (hazardous area)

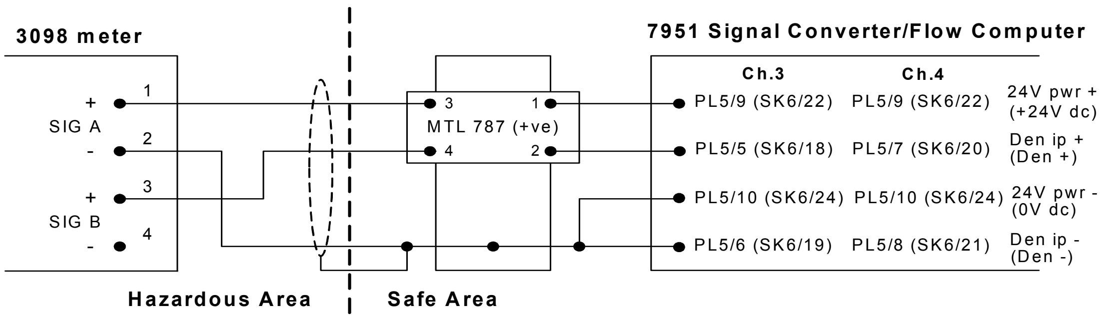
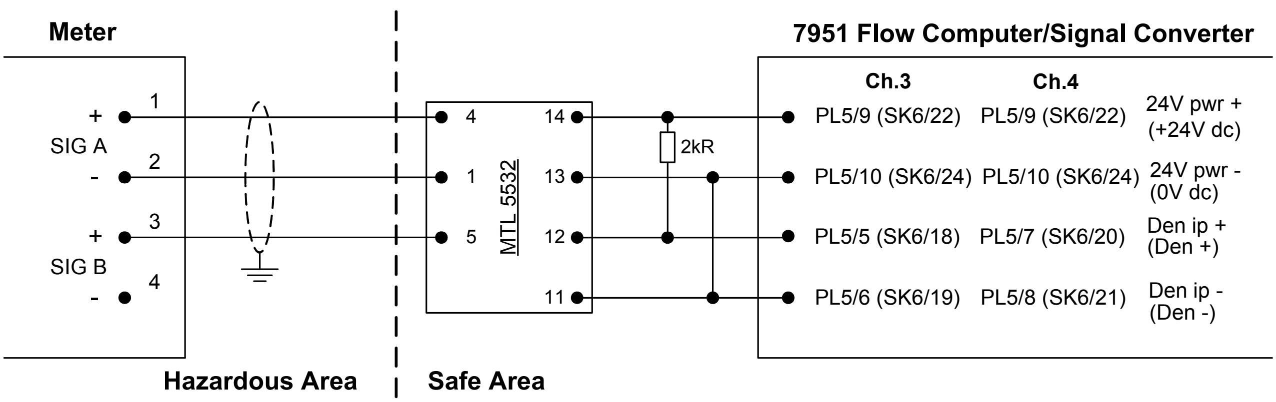


Figure 3-16 7951 flow computer/7951 signal converter gas specific gravity 3-wire system with galvanic isolator (hazardous area)



Note: The barrier trip level switch should be set to 3 volts.

Note: When the ATEX/IECEx-approved specific gravity meter is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

3.6 System connections (customer's own equipment)

3.6.1 Non-hazardous areas

Power supply to Density Meter: 15.5 to 33 Vdc, < 20 mA.

Power supply to PRT: 5 mA maximum

The frequency at which the meter is operating can be detected in one of two ways:

- For the 2-wire option, a 330 Ω series resistor should be used in the +ve power line. The electrical connections to be made are shown in Section 3.6.3. The signal across the 330 Ω resistor is greater than 2 V peak-to-peak. The minimum impedance of the signal measuring equipment should be 500 kΩ. Where necessary, the 1 nF capacitors will block the power supply DC voltage to the measuring equipment.
- For the 3-wire option, the frequency can be measured directly. The electrical connections to be made are shown in Section 3.6.4.

3.6.2 Hazardous areas

For details of hazardous area installations, see the ATEX/IECEx Safety Instructions booklet (available at www.micromotion.com) for ATEX/IECEx installations and see Appendix D for CSA installations.

3.6.3 Customer's equipment, 2-wire configuration

Figure 3-17 Electrical connections for meter 2-wire option used with customers' own equipment (safe area)

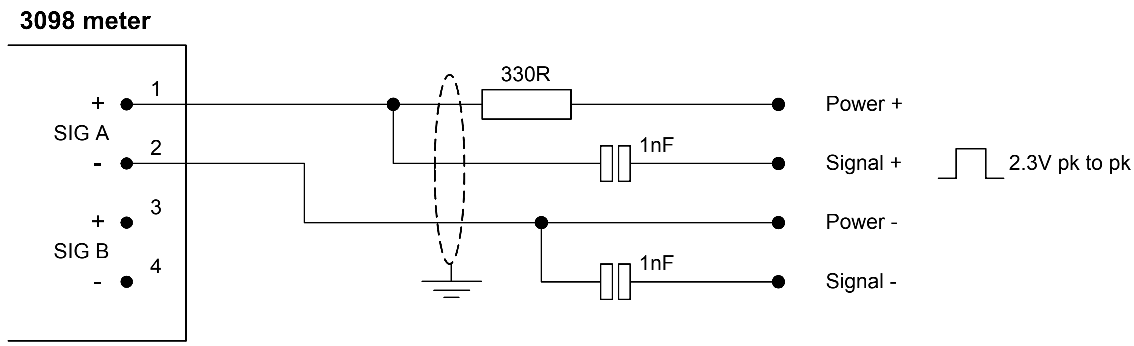
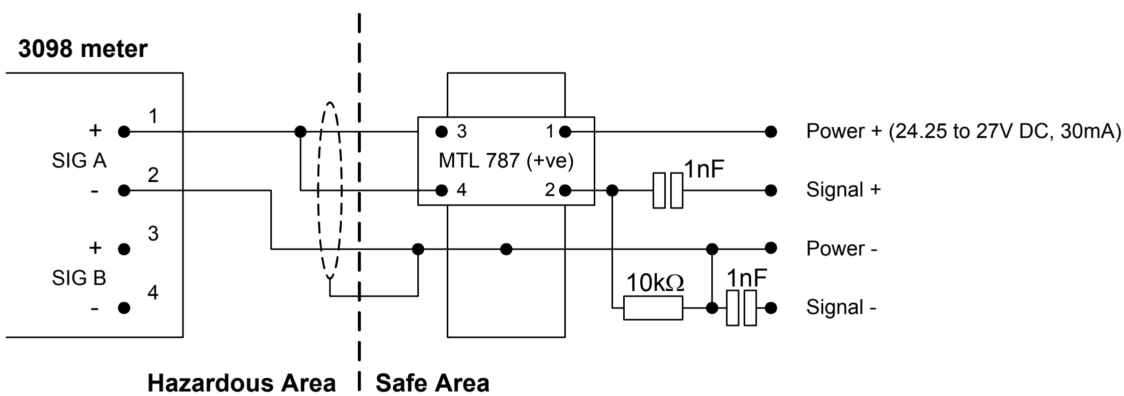


Figure 3-18 Electrical connections for meter 2-wire option used with customers' own equipment and shunt-diode safety barrier (hazardous area)



3.6.4 Customer's equipment, 3-wire configuration

Figure 3-19 Electrical connections for meter 3-wire option used with customer's own equipment (safe area)

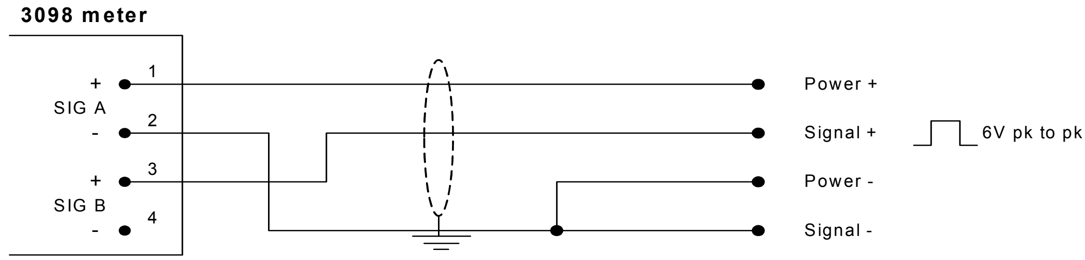
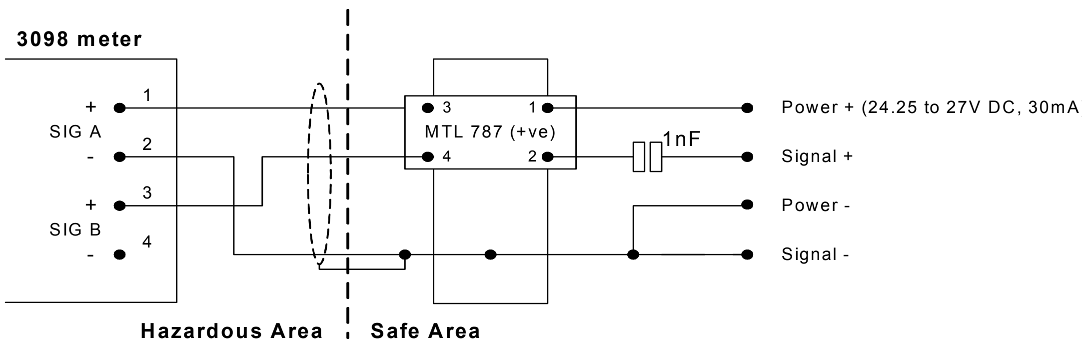


Figure 3-20 Electrical connections for meter 3-wire option used with customers' own equipment and shunt-diode safety barrier (hazardous area)



3.7 Post-installation checks

After installation, the following procedure will indicate to a high degree of confidence that the meter is operating correctly.

1. Electrical Check

   Measure the current consumption and the supply voltage at the meter amplifier. This should be within the following limits:

   - 15.5 Vdc to 33 Vdc (Safe Areas)
   - 15.5 Vdc to 24 Vdc (Hazardous Areas)
   - 10 mA at 24 V dc input (Nominal input current)
   - 17 mA maximum (Safe and Hazardous Areas, any input voltage)

2. Stability Check

   Check the stability of the frequency output signal using a period meter on a 1000-cycle count. The measurement scatter should be within ±2 ns. If this value is exceeded, it is likely that dirt is present on the sensing element. This test may be performed at any gas density, provided that the latter is not changing.

Chapter 4
Accuracy Considerations

This chapter provides a method for estimating the accuracy of 3098 specific gravity meter measurements under various conditions.

4.1 Accuracy considerations

The ‘controlled condition’ which establishes a direct relationship between density and the specific gravity of the sample gas is mainly determined by the pressure and the type of gas used in the reference chamber. The choice of reference chamber gas pressure is dependent upon:

- The span of specific gravity to be measured
- The expected change in sample gas supercompressibility, Z
- The accuracy required

The exact choice in reference gas pressure is made after considering all the error sources for that application. To simplify the selection, Table 4-1 is provided which can be reproduced by the user. In general, unless a pump is used to boost the pipeline pressure, the reference gas pressure at 20 °C must be at least 10% less than the minimum line pressure, to ensure gas flow over the operating temperature range.

4.1.1 Example 1

When a gas has a relatively low and reasonably constant specific gravity, and is available at a line pressure greater than 7 Barg (100 psig) such as natural gas measurement in the range 0.55–0.8, a very high accuracy is possible using a reference pressure of 7 Barg. (See Table 4-2 for a worked example).

4.1.2 Example 2

If large range specific gravity measurements are to be made, or where changes in the supercompressibility factor of the sample gases become significant, (such as in flare gases or air/CO_2 mixes), a much lower reference gas pressure is required. (See Table 4-3 for N_2/CO_2 mix).

4.1.3 Calculating parameters

Table 4-1 3098 specific gravity meter control pressure selection (natural gas)

3098 Specific Gravity Meter Control Pressure Selection					
Date:	**Type of gas:**	**Specific gravity range:**	**3098 serial no.:**	**Temperature coefficient of density meter:**	
Control pressure at 20°C	(lb/in^2 abs.) (bar abs.)	18 1.2	30 2	60 4	100 7
Density range at 20°C	(kg/m^3)	0.79–1.5	1.32–3.0	2.66–3.8	4.58–6.72
Measurement errors (% of FS specific gravity/°C) due to:					
Density meter temperature coefficient					
Gas compressibility of sample gas					
Velocity of sound in sample gas					
Reference chamber/relief valve		+0.007	+0.007	+0.007	+0.007
Total error					

Density range at 20°C

Calculated using equation:

Density range $P\rho_{air}G_{min}$ to $P\rho_{air}G_{max}$

where P = Absolute pressure in bars

ρ_{air} = Density in dry clean air (1.2 kgm^{-3} approximately)

G_{min} and G_{max} = Specific gravity minimum and maximum values

Density meter temperature coefficient error

Inversely proportional to density (therefore pressure) and is calculated as follows:

Temperature coefficient from calibration certificate = x kgm^{-3} /°C

At maximum density value of y kgm^{-3} :

Sensor equivalent temperature coefficient = x/y x 100%/°C

Gas compressibility error

This describes the deviation in gas compressibility of the sample gas compared with that of the reference chamber gas. The error is taken as 2/3 of the deviation caused by temperature change on the two gases at the reference pressure and is typically proportional to this pressure.

For information on the gas characteristics, see the International Standard Gas Tables.

Velocity of sound error

This error is taken as: – 0.0034 G %/°C, with G taken at maximum specific gravity.

Example 1

Table 4-2 3098 specific gravity meter control pressure selection (natural gas)

Date: 24th June 1997	**Type of gas: Natural Gas**	**Specific gravity range: 0.55 to 0.8**	**3098 serial no.: 000124**	**Temperature coefficient of density meter: –0.0003 kg/m3/°c**	
Control pressure at 20°C	(lb/in^2 abs.) (bar abs.)	18 1.2	30 2	60 4	100 7
Density range at 20°C	(kg/m^3)	0.79–1.15	1.32–2.0	2.66–3.8	4.58–6.72
Measurement errors (% of FS specific gravity/°C) due to:					
Density meter temperature coefficient		–0.026	–0.016	–0.008	–0.004
Gas compressibility of sample gas		±0.0003	±0.0003	±0.001	±0.002
Velocity of sound in sample gas		–0.003	–0.003	–0.003	–0.003
Reference chamber/relief valve		+0.007	+0.007	+0.007	+0.007
Total error		–0.022	–0.012	+0.003 to –0.005	+0.000 to –0.002

Example 2

Table 4-3 3098 specific gravity meter control pressure selection (N_2CO_2 mix)

Date: 28th July 1997	**Type of gas: N_2/CO_2 mix**	**Specific gravity range: 1.0 to 1.5**	**3098 serial no.:**	**Temperature coefficient of density meter: –0.0003 kg/m3/°c**	
Control pressure at 20°C	(lb/in^2 abs.) (bar abs.)	18 1.2	30 2	60 2	100 7
Density range at 20°C	kg/m^3	0.79–1.15	1.32–2.0	2.66–3.8	4.58–6.72
Measurement errors (% of FS specific gravity/°C) due to:					
Density meter Temperature coefficient		–0.026	–0.016	–0.008	–0.004
Gas compressibility of sample gas		±0.0003	±0.0003	±0.001	±0.002
Velocity of sound in sample gas		–0.003	–0.003	–0.003	–0.003
Reference chamber/relief valve		+0.007	+0.007	+0.007	+0.007
Total error		–0.014	–0.006	+0.006 to –0.010	+0.015 to –0.015

4.2 Calibration (for non-natural gas applications)

The instrument is supplied with its reference chamber empty and thus in an un-calibrated condition. After installation on site it is necessary to decide what reference chamber pressure to use, and then to charge and calibrate the instrument as described in Section 2.6.

Some examples of how to calculate these reference chamber pressures are given in Section 4.1.1 and Section 4.1.2, which show the best pressures for a natural gas and a N_2/CO_2 mix application.

Once this has been done, the gases to be used for calibration need to be defined. The calibration gases to be used must be of known specific gravities and substantially represent the properties of the line gas to be measured (for example, compressibility, viscosity) For example, if measuring a natural gas which is substantially methane and carbon dioxide, then these two gases in their pure forms or at defined specific gravities should be used in the calibration.

With this decided, the 3098 specific gravity meter can be calibrated by following the calibration procedure described in Section 2.6.

Note: In the case where only one calibration gas is available, the time period of the density meter at zero density/specific gravity (for example,vacuum conditions), which is included on the meter temperature coefficient calibration certificate, can be used as time period τ_y*. Under this condition, calibration is less accurate due to the non-homogenic condition of a vacuum and its effect on supercompressibility compensation. An example of the meter temperature coefficient calibration certificate is given below.*

Once the calibration has been performed, the coefficients can be calculated using equations (1) and (2) in Section 2.6. You can enter this information directly into the Calibration Certificate example in Section 4.4. For an online version of this certificate, download the Calibration Certificate Excel file at www.micromotion.com (located on the 3098 products page) or access the calcert.xls file on the floppy disk shipped with the product.

For more specific details on calibration see Appendix A.

4.3 Operation at low reference pressure levels

One of the design features of the 3098 specific gravity meter is that two orifice plates are used to control and regulate the flow of sample gas through the unit, one of which is placed at the output port and is used to reduce the stresses placed on the unit's diaphragm. It is important to note that in order to increase the sample gas flow rate, the pressure at the input port must be increased. As this pressure is increased, the pressure across the output orifice increases. If this pressure exceeds that of the gas inside the reference chamber, the diaphragm will not regulate the input gas pressure and hence not allow an specific gravity (SG) measurement.

For reference pressures greater than 3 bar absolute (3 bar A), this situation will not occur in the unit flow range of (0.2–60 cc/s). However, it may occur if the reference pressure is less than 3 bar A and the flow rate > 50 cc/s.

It is recommended that in order to achieve the optimum accuracy when performing specific gravity (SG) measurement, the corrections for VOS and compressibility are taken into consideration. This can be done by following the procedure described in Appendix A.

4.4 Calibration certificate example

3098 Calibration Certificate

Ref. No. ………… 000001 **Date :-** ………. 15-Apr-09

3098 Serial Number :- ………….. 000001

7812 Serial Number :- ………….. 000001

Cylinder Number :- ………….. 000001

Spoolbody Number :- ………….. 000001

INPUTS

Sample Gas Type :- Methane

Required Specific Gravity Span :- **0.5** to **7**

Selected Reference Pressure at 20°C :-

Calibration Gas **1** Type :-

Specific Gravity (SG_1) :- **0.554900**

3098 Output (τ_1) ………… **511.3467** µs

Calibration Gas **2** Type :-

Specific Gravity (SG_2) :- **0.967150**

3098 Output (τ_2) ………….. **518.4489** µs

Note : Where the output is required in Relative or Standard Density units, simply substitute these values for the Specific Gravity values.

CALCULATIONS :-

Since the Specific Gravity,

$$SG = K_0 + K_2 \tau^2 \qquad \text{……….1}$$

where

$$K_2 = \frac{SG_1 - SG_2}{\tau_1^2 - \tau_2^2} = \mathbf{0.0000563659} \qquad \text{……….2}$$

$$K_0 = SG_2 - K_2 \tau_2^2 = \mathbf{-14.1834087265} \qquad \text{……….3}$$

T E M P E R A T U R E   C O E F F I C I E N T

C A L I B R A T I O N   C E R T I F I C A T E

3098 SPECIFIC GRAVITY METER

Serial Numbers:

Instrument	000001
Amplifier	000001
Cyclinder	000001

Pressure Test

Units pressure tested to 300 p.s.i.g.

Datum Periodic Time

Time period with vacuum at 20°C (μs)504.398
(zero specific gravity)

Temperature Coefficients

Cylinder coefficient at 20°C (μs/°C)0.0013

Density equivalent at 20°C (Kg/m^3/°C)0.0006

```
     ####     ##    ##      ##  ####    ##      ######
     ####     ##    ##      ##  ####    ##      ######
   ##      ##  ##  ####  ####  ##  ##  ##      ##
   ##      ##  ##  ####  ####  ##  ##  ##      ##         --------------
     ##    ######  ##  ##  ##  ####    ##      ####      |  FINAL TEST  |
     ##    ######  ##  ##  ##  ####    ##      ####      |              |
       ##  ##  ##  ##      ##  ##      ##      ##        |              |
       ##  ##  ##  ##      ##  ##      ##      ##        |              |
   ####    ##  ##  ##      ##  ##      ######  ######    |              |
   ####    ##  ##  ##      ##  ##      ######  ######    |              |
                                                          --------------
```

3098CERTGEN V1.0 DATE: xx-xxx-xx

Chapter 5
Maintenance and Fault Finding

5.1 Introduction

This chapter deals with the recommended servicing and maintenance that can be carried out under field conditions, including calibration checks, fault-finding procedures and simple maintenance. If a fault is traced to a reference chamber malfunction, it is strongly recommended that the repair of the faulty unit be restricted to a qualified engineer or that the faulty unit be returned to the factory (see Appendix C).

If a calibration check reveals a significant error, the cause of this error (for example, reference chamber leak, deposition on the vibrating cylinder) should be thoroughly investigated before any re-calibration attempt is made.

5.2 Calibration check

It is normally good practice to carry out periodic checks on the system accuracy. This is simply achieved by passing a gas of known specific gravity through the instrument as previously detailed in Section 2.6. It is preferable that the specific gravity of this calibration gas lies within the specific gravity range of the system under test since this will simplify the system check procedure. However, a gas whose specific gravity is outside this range can be used if its characteristics are similar to those of the system line gas.

5.3 Fault finding

If any adverse or suspect readings occur upon checking the calibration, the possible causes for this can be summarized into 4 groups:

- Instrument over-reads
- Instrument under-reads
- Erratic instrument readings
- Meter faults

5.3.1 Instrument over-reads

This is generally due to deposition, condensation or corrosion on the vibrating cylinder walls.

The effects of deposition and condensation can be removed from the cylinder by carefully cleaning the cylinder walls (once the density meter has been removed from the 3098 specific gravity meter) although corrosion cannot be dealt with this way.

If the cylinder is corroded or damaged in any way (for example, dents and scratches) then it must be replaced with a new unit.

5.3.2 Instrument under-reads

This is most probably due to a gas leak from the reference chamber. Before dismantling the instrument it is desirable to locate the leak, the cause of which may be one of the following:

(i) Reference chamber to sample gas path

Parts affected are:

- Diaphragm
- Reference chamber valve
- Reference chamber metalwork.

This type of leak can be identified by using the following test.

Charge the reference chamber to a high pressure (up to 7 Bar A maximum) and then isolate by closing the reference chamber valve. Vent the sample gas path at the instrument's inlet and outlet to atmosphere, then seal by closing the inlet and outlet line valves.

If gas is leaking into the sample gas flow path, this will be indicated by the change in output signal from the density meter.

Alternatively, if the leak rate is influenced by whether the sample gas path is at atmospheric pressure or at the line operating pressure, then this is indicative of a leak into the sample gas flow path.

(ii) Reference chamber to atmosphere

Parts affected are:

- Diaphragm
- Sealing gasket (meter)
- Reference chamber valve pipework
- Reference c+hamber metalwork

This type of leak can often be traced by the application of a soap solution, or 'Snoop', and bubble observation. Unlike the previous type of leak this will not be influenced by sample gas path pressure.

If the leak is due to a faulty gasket seal, diaphragm, or reference chamber valve then a serviceable replacement should be fitted.

If in doubt, advice should be sought from the factory – contact details are on the back page of this manual.

(iii) Erratic instrument readings

These can be caused by:

- Electronic fault

  This can exist in either the meter or its associated electronics.

  If an independent frequency generator is available, this can be used to check the performance of the flow computer/signal converter.

  If the fault is in the meter amplifier, this can be changed with no degradation in performance.
- Vibrating cyclinder

  If the sample gas flow is stopped by closing the inlet valve, the time period signal should drop slightly to a steady value or, if there is a small leak, continue to drop slowly. Should the reading remain erratic, it is likely that there is deposition on the vibrating cylinder which needs to be stripped, cleaned and re-assembled.
- Pressure control valve

If the erratic signal is only present while there is a flow of sample gas through the unit, then the fault is likely to be due to a malfunction of the pressure control valve, brought about by the presence of dirt. In this case the diaphragm (and hence valve mechanism) should be stripped down, cleaned and re-assembled. Any poor seals or damaged parts should be replaced. Alternatively, the gas pressure may be falling below that of the designed input condition.

- Meter faults

  These faults can be found by a few simple tests:

  - Spoolbody Assembly: The magnetic drive and pick-up assembly (spoolbody) can be checked visually for problems and also electrically for continuity, by measuring the resistance of the drive and pick-up coils. The resistance of each coil should be (72±10)Ω at 20°C.
  - Meter Amplifier: If careful examination of the sensing element and spoolbody assembly does not reveal the cause of the problem, the amplifier should be replaced. This will show whether the problem is with the amplifier.

Note: A check of the amplifier current consumption is a good indicator of the amplifier's health. A further test to check the amplifier is to change the supply voltage across its operating range and check that the time period does not change.

5.4 Maintenance

The supplied coalescing filter should be checked regularly for liquid and particulate contamination. The frequency of checking is dependent upon the condition of the sample gas.

The particulate filters fitted in the 3098 should also be checked routinely for contamination and should be replaced when dirty.

Apart from scheduled calibration checks and filter replacements no other routine maintenance should be required.

When a fault is suspected, the 3098 specific gravity meter can be easily dismantled to expose the section that needs inspection. A full dismantling procedure to major component level is described below.

1. Main meter (3098 specific gravity meter) removal: Removal of the complete unit from its installation, allowing all other servicing to be performed.
2. Density meter removal: Removal of the sensing element to a clean environment where further dismantling can take place.
3. Reference Chamber Diaphragm removal: (Performed after stage 1).

General notes

- All gaskets, O-rings and the diaphragm are to be lightly greased with silicone grease MS4 before re-assembly. Gas connection threads to be sealed using PTFE tape or Loctite 572.
- Loctite 221 is to be applied to all screws during re-assembly.
- New gaskets should be fitted on re-assembly.
- Any re-assembly must be followed by a leak test, procedure 5.2.7.

Before any servicing is attempted the 3098 specific gravity meter must be isolated from both the gas and electrical supplies.

5.4.1 Main meter (3098 specific gravity meter) removal (Figure 5-1)

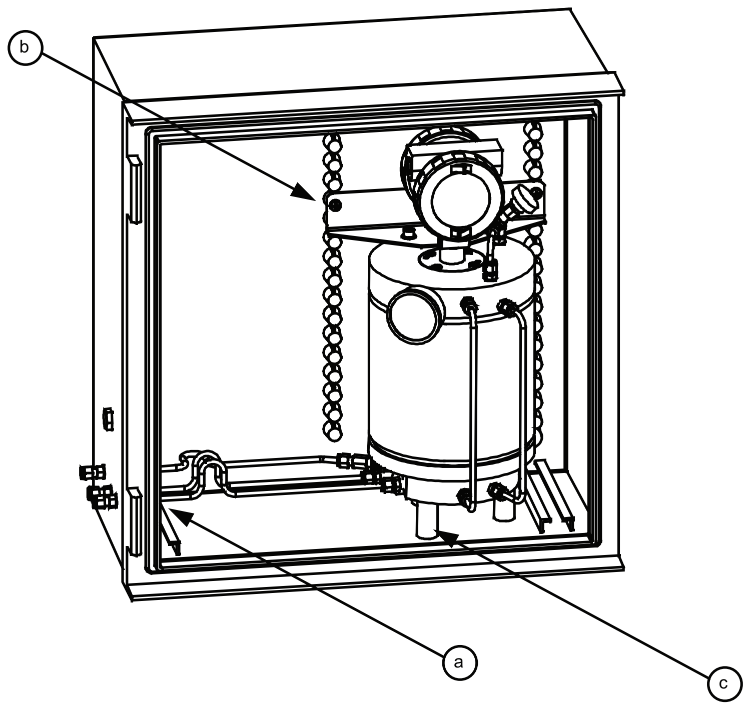
The instructions in this section apply only to 3098 specific gravity meters supplied with an enclosure (see Safety guidelines on page 1). In all other cases, please refer to the system installer.

1. Ensure that the 3098 specific gravity meter has been isolated from the gas and electrical supplies. Vent the instrument to atmospheric pressure. The reference chamber may remain charged with gas unless a reference chamber diaphragm requires servicing.

For some gases, such as methane, it is imperative to vent the reference chamber to atmospheric pressure whenever the 3098 specific gravity meter has to be taken off-line.

2. Disconnect the 3098 specific gravity meter externally from the system pipework at the side of the enclosure having vented the reference chamber (if required). Cover all exposed gas connections.
3. The 3098 specific gravity meter may be removed from its installation while still inside its enclosure, or it can be separated at this stage, leaving the box in situ. If the latter is required then continue from 5.
4. The enclosure can now be removed from its installation by unscrewing the four mounting feet fixings.
5. Once the electrical wiring has been disconnected from the meter and the cable removed from the gland, the instrument can be further dismantled. The 3098 specific gravity meter metalwork can be removed from the enclosure as described in steps 6–8 and transported to a clean area for further servicing.
6. Remove the enclosure door by pulling out the two retaining pins. Undo the three Swagelok pipe fittings that connect the gas lines to the unit at the enclosure wall (item a). When this is done, remove the two recess headed screws that hold the unit’s mounting bracket to the rear of the enclosure (item b).
7. Loosen and remove the three bolts at the base of the box that hold the unit’s feet (item c).
8. Carefully remove the unit from the enclosure by moving it to the right to disengage the pipes from their fittings. Take the metalwork to a clean area.
9. The 3098 specific gravity meter is installed using this procedure in reverse order. All gas pipe connections will require leak testing.

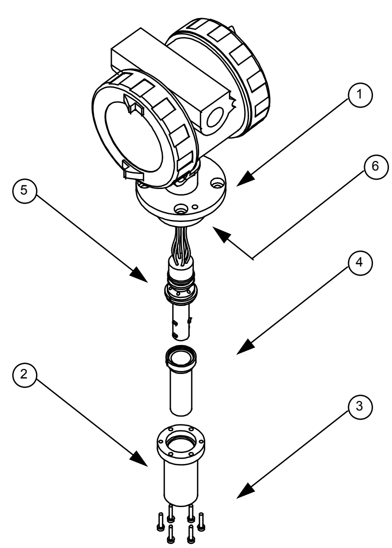
Figure 5-1 **3098 specific gravity meter general assembly schematic (typical enclosure)**



5.4.2 Density meter removal (Figure 5-2)

1. With the 3098 specific gravity meter disconnected and removed from its enclosure, the density meter can be removed from the top plate by undoing the four M6 bolts that hold it in place.

Figure 5-2 **Density meter exploded view**



2. Use two of the removed M6 bolts to jack the meter from its housing using the two threaded holes found in the mounting housing (item 6). **WARNING! Do not try to lever the unit out – this will damage the sealing O-ring and the vibrating element.**

The aperture left in the 3098 specific gravity meter by this removal should be covered to stop dust or dirt getting into the meter chamber. The meter itself can now be taken to a clean environment to be serviced further.

The density meter is refitted by locating it in the top plate and lowering it until it sits on the sealing O-ring. **IMPORTANT! Do not force the meter in place by pushing downwards.**

Tighten the four bolts in sequence to gradually ease the meter into place. The bolts holding the density meter in place should be tightened to a maximum torque of 10 Nm and should be treated with proprietary thread locking compound (for example, Loctite).

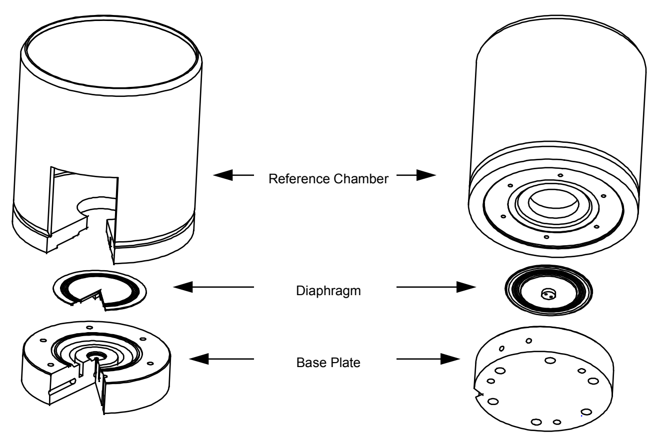
The meter amplifier housing can be easily removed by releasing the clamp that holds it to the meter body (mounting housing) and undoing the spoolbody wire connections inside. A more detailed description of the electronics inside the housing is given in Chapter 3.

5.4.3 Reference chamber diaphragm removal (Figure 5-3)

The diaphragm that regulates the sample gas pressure to that of the reference chamber is held in between the welded assembly and the base plate. The following procedure shows how to access and service this part.

The figure below shows two views for clarity with top plate and pipework not shown.

Figure 5-3 Reference chamber diaphragm section



1. As the diaphragm produces a gas tight seal for the reference chamber, before any servicing of this part is done, the reference chamber must be vented to atmospheric pressure.
2. With the 3098 specific gravity meter out of its enclosure (see Section 5.4.1) remove the three unit feet and stand the metalwork upright.
3. Using a 9/16″ spanner, undo and remove the two gas pipes that connect the base plate to the top plate.

4. Gently rest the 3098 specific gravity meter on its side and undo the six M6 bolts that lock the base plate to the reference chamber.

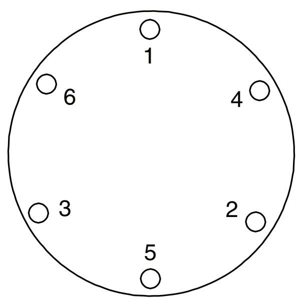
Note: Care must be taken not to bend or damage the three gas pipelines that originate from the base plate.

5. The diaphragm is exposed once the base plate has been removed.
6. As the diaphragm is a single-moulded piece part, servicing consists of either changing the sealing O-ring or changing the diaphragm itself.

5.4.4 Re-assembly procedure

1. Invert the 3098 specific gravity meter so that the diaphragm counter-bore faces upwards.
2. Locate the diaphragm assembly into the counter-bore housed in the welded assembly–not the base plate.
3. Carefully replace the base plate over the diaphragm, making sure that the diaphragm is not moved from its central position in the counter-bore and that the connectors line up for the two 'base-to-top-plate' gas pipelines.
4. Place the bolts into their counter-bores and tighten them in ascending order as shown in the diagram below:

Figure 5-4 Order to tighten bolts in counter-bores



5. Replace the two 'base-to-top-plate' gas pipelines and the density meter (if it has been removed) and perform a leak check on all seals described in Section 5.4.7.
6. The 3098 specific gravity meter can now be replaced in the main enclosure, by reversing the procedure described for Main meter (3098 specific gravity meter) removal (Figure 5-1).

5.4.5 3098 specific gravity meter filter change procedure

1. Remove unit from installation and enclosure as described in Section 5.4.1.
2. Place the unit on its side and loosen the fittings that retain the input gas interconnection pipe.
3. Once this pipe has been removed, loosen and remove the filter fitting that screws into the unit base plate.
4. The filter element cannot be removed from its housing, so the complete fitting must be changed.
5. The new filter should be inserted into the base plate, using PTFE tape to produce a gas tight seal. Care should be taken to ensure that no stray parts of PTFE tape fall into the instrument.

6. Re-assembly is the reverse of steps 2 and 1 above.

Note: Once the unit has been replaced into its enclosure, a leak check must be performed before on-line operation.

5.4.6 Further servicing of the density meter (Figure 5-5)

Once the density meter has been removed from the 3098 specific gravity meter metalwork and the electronics housing removed, the unit can be further serviced by following the instructions below:

The cyclinder wall is fragile. Great care must be shown during the removal, handling, and refitting of the cyclinder and its housing. Hold only by the clamping section.

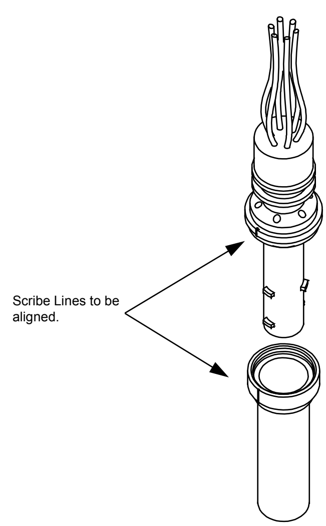
1. Referring to Figure 5-2, remove the six screws (item 3) which secure the cylinder housing (item 2) to the mounting housing (item 1).
2. Exercising great care, ease off the cylinder housing in an axial direction, allowing access to the cylinder/spoolbody assembly.
3. Carefully lift off the cylinder (item 4) and clean by lightly wiping with a lint-free tissue soaked in an appropriate solvent.
4. Again, exercising great care, ease out the spoolbody (item 5). Clean the spoolbody and examine for corrosion.

If no corrosion or other damage is apparent on any of the piece parts, the instrument may be reassembled in reverse order. During re-assembly of the sensing element, special attention is required to correctly orientate the cylinder/spoolbody combination (see Figure 5-5).

Re-fit the meter to the 3098 specific gravity meter, by following the operations above in reverse order, making sure that the scribe marks align as shown in Figure 5-5.

Note: It is recommended that O-rings be renewed during re-assembly and lightly coated with silicone grease.

Figure 5-5 Spoolbody/cylinder alignment



5.4.7 Leak testing the 3098 specific gravity meter

Leaks incurred during servicing can be categorized under two main headings:

- Reference chamber leaks
  a. Charge the reference chamber to 6.5 bar G using any clean dry gas.
  b. Pass a gas of constant specific gravity (for example, nitrogen) through the instrument, and when stabilized, record the time period.
  c. Repeat operation twice every day for three or four days, ensuring that there are no large temperature changes at each reading. A downward drift in the time period indicates a leak.

Note: Further tests can be done in order to define the nature of the leak. These procedures are laid out in Section 5.3.

- Gas Path to Atmosphere Leaks
  a. Apply any clean dry gas at a pressure of 6.5 bar G to the meter.
  b. Apply a soap solution, or 'Snoop', to all disturbed areas of the meter and observe for any bubble formation.
  c. Seal as required and on completion of a satisfactory leak test, vent the meter to atmosphere.

5.4.8 Post-maintenance tests

A density measurement check on ambient air will verify that the vibrating cylinder is functioning correctly. A full calibration followed by a calibration check preferably using two suitable calibration gases, as previously described, will be necessary to prove the system. This check, when carried out over a period of time acts as a leak detection test.

5.4.9 Worked example of calibration certificate

This example relies on the following criteria being assumed:

Specific gravity	0.5–0.7
Gas line pressure	15 Bar
Reference chamber pressure	7 Bar G
Calibration gases CH_4 and N_2	SG values 0.5549 and 0.96715

The calibration gases in their pure state are passed through the meter and their respective periodic times measured. From this information, the coefficients are derived.

Chapter 6
Specifications

6.1 3098 specific gravity meter specifications

*Note: Some parts of this specification (marked with *) cannot be guaranteed for 3098 specific gravity meters supplied without an IP-rated enclosure* (see *Safety guidelines on page 1).*

6.1.1 Performance

Table 6-1 Performance specifications

Specification	Description
Specific gravity limits	0.1–3 (typical)
Fluid	Dry, clean, non-corrisive
Accuracy(1)	Up to ±0.1% reading*
Repeatability(1)	±0.02% reading*
Temperature coefficient	±0.005% / °F (±0.01% / °C)*
Temperature range	–22°F to +122°F (–30°C to +50°C), or as limited by gas dew point
Control pressure at 20°C	1.2 to 7 bar absolute (17 to 101 psia)
Supply Pressure	Maximum: control pressure + 15% Maximum: control pressure + 100%, up to a maximum of 12 bar absolute
Gas flow rate	0.012 to 3.66 in^3/s (0.2–60 normal cc/s)
Response time	Less than 5 s upon entry into enclosure with flow at 3.66 in^3/s (60 normal cc/s)
Output signal	Nominal 6 V peak-to-peak for 3-wire system 2 to 3 V peak-to-peak across 330-Ω resistor for 2-wire system
Operating frequency range	(1960 ±10%) Hz at 0 kg/m^{-3} (1580 ±10%) Hz at 60 kg/m^{-3}
Built-in filter	7 μm
Calibration	By gas sample of known specific gravity

(1) These figures apply to the measurement of a typical natural gas at a reference pressure of about 6 bars. Two gases of known specific gravity are required for calibration (typically nitrogen and methane). In practice, the accuracy achieved will depend on the care taken in calibration. An accuracy of 0.1% of ready can readily be obtained.

6.1.2 Electrical

Table 6-2 Electrical specifications

Specification	Description
Power supply	+15.5 to 33 Vdc, 20 mA maximum
Electromagnetic compatibility	Approved to: • IEC 61326-1:2006, IEC 61326-2-3:2006 • EMC directive 2004/108/EC

6.1.3 Mechanical

Table 6-3 Mechanical specifications(1)

Specification	Description
Gas connection	Swagelock compression fittings for 1/4” (6.35 mm) O/D pipe
Enclosure rating	Meter rated to IP65 when mounted in enclosure
Enclosure dimensions	See drawings in Section 2.7
Enclosure weight	
• Small enclosure (3098E*** and 3098H***)	44 lb (20 kg) (approximate)
• Large enclosure (3098G*** and 3098K***)	68 lb (31 kg) (approximate)
Materials	Process gas must be compatible with Ni-Span-C902, Stainless Steel AISI 316, Stycast catalyst 11, and 6082 grade Aluminum alloy

(1) Only valid for meters supplied with IP-rated enclosure (see Safety guidelines on page 1).

6.1.4 Safety

For ATEX/IECEx installations, see the ATEX/IECEx Safety Instructions booklet and PED Safety Instructions booklet (available at www.micromotion.com).

For CSA installations, see Appendix D.

Appendix A
Performance Optimization

A.1 Introduction

The 3098 specific gravity meter uses a vibrating element density sensor that is located within a pressure regulating system. The arrangement is such that the density output signal can be directly related to the specific gravity or relative density of the gas.

Operation of the meter involves charging a reference chamber to a defined pressure and then calibrating the output signal by using gas samples of known relative density. In order to reduce the effect of systematic errors associated with the density sensor and the non-ideal behaviour of gases, a number of procedures must be carefully followed. The procedures listed in this document should form the basis for more specific and clearly defined user procedures. Reference should also be made to the calibration details given in Section 2.6.

A.1.1 Density sensor

The vibrating cylinder density sensor is able to measure the density of gases with very high resolution and accuracy. Its two major potential error sources are temperature coefficient and a gas composition influence due to the effects of the velocity of sound in the gas.

The effect of the sensor temperature coefficient is directly related to the operating density and hence the operating pressure. If the operating pressure is doubled, the effect is halved.

The gas composition influence is substantially related to the relative density of the gas and not its operating condition. In consequence, this effect is substantially eliminated by the calibration procedure. However, best results are achieved if the calibration gases are of similar type to that of the sample gases.

A.1.2 The non-ideal behaviour of gases

This behaviour will affect the operation of the measurement system since the measurement of density at the operating condition is not only related to the relative density of the gas but also to its compressibility factors. The consequences of this characteristic are as follows:

- If the operating temperature changes, so will the value of the compressibility factor and this would be seen as an instrument temperature coefficient. However, if the reference chamber contains a similar gas, the Z factor (compressibility) changes are self-cancelling and hence no resultant effect materializes. For this reason, and if a low system temperature coefficient is required, it is important that the reference chamber gas is similar to the measurement gas. Operating at low reference chamber pressure will also reduce this effect.
- Any compressibility factor differences between the calibration gases and the sample gas will be seen as measurement offsets. In consequence, it is important that the calibration gases do closely represent the major constituents of the sample gas or that the calibration procedure makes allowances for any such offsets. Since compressibility factors are related to operating pressure, it follows that this offset is minimized when operating at low reference chamber pressures.

A.1.3 Selection of reference chamber pressure

The reference chamber pressure must always be above the vent pressure to ensure sample gas flow. If venting to atmospheric pressure, this means that the reference chamber pressure should be above 1.2 bar absolute and below the maximum of 7 bar absolute. The actual pressure should be selected to give minimum measurement errors due to temperature changes and calibration method.

To summarize:

- To minimize density sensor temperature coefficient, use high pressure.
- To minimize Z changes with temperature, use low pressure.
- To minimize Z effect on calibration, use low pressure.
- To minimize errors in readout electronics, use high pressure.

Note: When sample gas is flowing through the instrument, the reference chamber pressure is indicated on a dial gauge within the insulated enclosure. The indicated pressure is in bar gauge whilst the pressures quoted in this text are in bar absolute.

A.1.4 Selection of calibration gases

The measurement accuracy of the specific gravity meter can be not better than that defined by the quality of the calibration gases. Furthermore, the calibration gases should substantially represent the characteristics of the expected sample gases, especially with respect to their compressibility characteristics.

For example, the use of pure certified methane as one calibration gas and the use of a typical certified gas mix as the other calibration gas would yield good results. However, since it may be difficult to obtain a certified gas mix, and also since some gas mixes will stratify in their containers and hence give unreliable quality, it is often better to use two pure gases such as certified methane and certified nitrogen. In this case it may be necessary to modify the calibration procedure to make allowance for any non-ideal characteristics of the sample gases.

A.2 Recommended calibration methods

From the previous descriptions it can be appreciated that there is a choice of calibration procedures. These differ in detail to suit the operating conditions, the types of gas to be measured, and the availability of calibration gases. However, all calibrations can be separated into three general tasks as follows:

A.2.1 General calibration method

Selection of reference chamber gas

This gas should ideally be similar to the sample gas as far as compressibility characteristics are concerned (it is usual for the sample gas to be used in the reference chamber) in order to minimize the temperature coefficient of the instrument.

Selection of reference chamber pressure

This pressure should be set to a value which minimizes the temperature coefficient and also any calibration errors which result from using non-representative calibration gases.

Calibration and sample gases

Having charged the reference chamber to the selected pressure chamber pressure, then suitable adjustment should be made to the calibration coefficients to ensure minimum error when using the sample gases. These calibration adjustments can be calculated from a knowledge of the compressibility factors of the calibration and sample gases, or by establishing the necessary offsets by measurement experience. Section A.2.2 details the procedures which can be adapted to suit any specific calibrations involving gas mixes, and highlights the special problems entailed.

A.2.2 Specific calibration method

Example for natural gas using methane and nitrogen as calibration gases.

Selection of reference chamber gas

This gas should ideally be similar to the sample gas as far as compressibility characteristics are concerned (it is usual for the sample gas to be used in the reference chamber) in order to minimize the temperature coefficient of the instrument.

Selection of reference chamber pressure

The reference chamber pressure is selected as follows:

- To minimize the temperature coefficient (see Section 4.1.3).
- To minimize the compressibility effect between the calibration and sample gases.

Calibration

Apart from the temperature coefficient characteristics, the major potential error sources are:

- The velocity of sound effect (*VOS*) of the gas
- The compressibility factor (Z) of the gas

Velocity of sound effect

The velocity of sound effect on the sensor is such that:

A1

$$\rho = \rho_i\left(1 - \frac{K_3}{(c\tau)^2}\right)$$

where ρ = Line density

ρ_i = Indicated density assuming infinite VOS

K_3 = VOS coefficient, typically 4.41×10^3

τ = Sensor periodic time, typiclly 515 μs

c = Velocity of sound in the gas in meters per second

The velocity of sound in a gas can be determined as follows:

A2

$$c = \sqrt{\gamma\frac{P}{\rho}}$$

where γ = Ration of specific heats

P = Line pressure in bars

ρ = Line density

For an ideal gas at 20°C, equation A2 can be simplified to:

A3

$$c = 1562\sqrt{\frac{\gamma}{M}}$$

where M = Molecular weight of the gas

Therefore, substituting into equation A1 and simplifying:

A4

$$\rho = \rho_i\left(1 - \frac{M}{\gamma}6.95 \times 10^{-4}\right)$$

where $\left(1 - \frac{M}{\gamma}6.95 \times 10^{-4}\right)$ can be referred to as the the velocity of the sound factor, V_P

For example $\rho = \rho_i V_F$

It follows that the *VOS* factor is substantially related to the molecular weight or base density, the main additional influence being due to unrelated differences in the specific heat ratios. From equation A1, the *VOS* factors (V_F) for the calibration gases and sample gases can be calculated and tabulated, see the example illustrated in Table A-2.

Compressibility factor

The normal or base density (ρ_s) is given by the equation:

A5

$$\rho_s = \rho \times \frac{P_s}{P} \times \frac{t}{t_s} \times \frac{Z}{Z_s}$$

where P_s, t_s, Z_s = Values of pressure, temperature, and compressibility at standard conditions

ρ, P, t, Z = Values of density, pressure, temperature, and compressibility at measurement conditions

The basic operation of the instrument allows the pressure/temperature ratio to be considered constant, hence equation A5 reduces to:

A6

$$\rho_s = \rho K \frac{Z}{Z_s}$$

$$\rho_s = \rho K Z_F$$

where K = Calibration constant

Z_F = Compressibility factor

The Z factor for gases or gas mixtures may be obtained from reference sources or may be derived from:

For Nitrogen at 20°C:

A7

$$Z = 1.0 - P(2.38 \times 10^{-4})$$

where P = The gas pressure in bar absolute

For a methane-based gas mixture at 20°C:

A8

$$Z = 1.0 + P[1.7 \times 10^{-4} + 6 \times 10^{-5}(M) - 1.13 \times 10^{-5}(M^2) + 7.2 \times 10^{-3}(I)]$$

where P = The gas pressure in bar absolute

M = The mean molecular weight of gas

I = Volume/mole fraction of inerts (for example, N_2 and CO_2

The Z factors of the calibration gases and the sample gases should be calculated at both base and operating conditions in order to establish the compressibility factor V_F and then tabulated as shown by the example in Table A-2.

Combination of V_F and Z_F

By combining equations A4 and A6, gives:

A9

$$\rho_s = K\rho_i V_F Z_F$$

The combination of V_F and Z_F should also be tabulated as shown in Table A-2. The combined factor E_F can then be used to determine the anticipated measurement errors on sample gases when using the two selected calibration gases. Furthermore, the tabulated results can be plotted to show the error trends and uncover the most suitable calibration gas selection and/or calibration offset to give minimum measurement error on the sample gases (see Figure A-1).

Table A-1 is provided to identify the variables used in equations A10 and A11.

Total factor calculations

Total factors when using calibration gases as reference:

A10

$$E_{1a} = 1 - \frac{X(1-x)}{A} - \frac{(A-X)[Y(1-y)-X(1-x)]}{A(Y-X)}$$

E_{1B} = As in equation A10 but substituting B for A

E_{1C} = As in equation A10 but substituting C for A

Total factors when using methane and sample gas *C* as reference:

A11

$$E_{2y} = 1 - \frac{X(1-x)}{Y} - \frac{(Y-X)[C(1-c)-X(1-x)]}{Y(C-X)}$$

E_{2a} = As in equation A11 but substituting A for Y

E_{2b} = As in equation A11 but substituting B for Y

Note: If sample B was used as the calibration gas the equation as in A11 would be used with B substituted for C and b substituted for c.

Legend for Table A1

Column		Descripton of Column Contents
1		Gas type and use function - calibration or sample, for example
2	M	Molecular weight of gas
3	γ	Ratio of specific heats
4	Z	Compressibility factor at base conditions
5	ρ_s^{true}	Base density of gas
6	V_F	Velocity of sound factor
7	Z	Compressibility factor at reference chamber pressure
8	Z_F	Compressibility correction factor
9	E_F	Total factor
10	$\Delta_F\%$	The value
11	E_1	Calculated total factor using calibration gases as reference
12	$\Delta_1\%$	The value which is the anticipated error which results from a simple methane/nitrogen calibration. In general these errors are mainly defined by the compressibility factors and in consequence will be reduced in relation to the reference chamber pressure.
13	E_2	Calculated total factor using methane and sample gas as reference
14	$\Delta_2\%$	The value which is the anticipated error which results from a methane/sample gas C calibration. This is directly equivalent to a methane/nitrogen calibration in which the nitrogen base density Y' is used in place of the true base density, for example, an offset has been added. Once again the errors can normally be reduced by reducing the reference chamber pressure.
15	$\rho_s^{ind.}$	Values of which are anticipated in order to obtain zero error for methane and sample gas C.

Summary

This appendix describes the major systematic errors of the 3098 specific gravity meters and methods of minimizing their effects by correct selection of the reference chamber pressure and calibration procedure to be used. Whether calibration is performed using truly representative calibration gases or whether pure gases such as methane and nitrogen are used will, to some extent, depend upon the availability of each of those gases. If using pure gases for calibration, the method and example clearly show how better accuracy can be achieved on the sample gases by using modified values of base density for the calibration gases. These modified values are as determined from Table A-1, Column 15 and the resultant errors are as shown in Column 14.

An alternative method of deriving the modified values of base density has been included in the calculations for Table A-2. Its results compares favourably with the tabulated result in Column 15 but is not as informative in error identification as Table A-2.

Table A-1

			At base conditions		At sample gas conditions of °C and bars									
1 Gas type	2 Molecular mass M(1)	3 γ at sample conditions (2)	4 Z_s (3)	5 ρ_s^{true} (4)	6 V_F (5)	7 Z(6)	8 Z_F (7)	9 E_F (8)	10 Δ_F% (9)	11 E_1 (10)	12 Δ_1% (11)	13 E_2 (12)	14 Δ_2% (13)	15 $\rho_s^{ind.}$ (14)
Cal			s	X				x		x		x		X
Cal				Y				y		y		E_{2y}		Y’
Sample				A				a		E_{1a}		E_{2a}		A’
Sample				B				b		E_{1b}		E_{2b}		B’
Sample				C				c		E_{1c}		c		C’

(1) Column 2 data derived from page x.x or other suitable tables.
(2) Column 3 data is interpolated from International Standard Gas Tables (for example, IUPAC) at SAMPLE GAS conditions.
(3) Column 4 data is interpolated from International Standard Gas Tables (for example, IUPAC) at BASE GAS conditions.
(4) Column 5 data calculated using:

$$\rho_S = \frac{P_S M}{0.0831434 \times T_S \times Z_S}$$

(5) Column 6 data calculated using:

$$V_F = 1 - \frac{M}{\gamma} \times 0.000695$$

(6) Column 7 data calculated using Z = 1–0.000238P for Nitrogen; Z = 1+P(0.00017+6E–05M x 1.13E–05M^2+7.2E–03 x I) for CH_4, where P is pressure in bars absolute and I is volume/mole fraction of inert gases.
(7) Column 8 data calculated using Z_F = Column 7/Column 4.
(8) Column 9 data calculated usig E_F = Column 6 x Column 8.
(9) Column 10 data calculated using Δ_F% = (1–Column 9) x 100%.
(10)Column 11 data is E_1 = x or y, or calculated for E_{1a}, E_{1b}, or E_{1c} (see A10 on page 52).
(11)Column 12 data calculated using Δ_1% = (Column 11–Column 9) x 100%.
(12)Column 13 data is E_2 = x or c, or calculated for E_{2a}, E_{2b}, or E_{2c} (see A11 on page 52).
(13)Column 14 data calculated using Δ_2% = (Column 13–Column 9) x 100%
(14)Column 15 data calculated using:

$$\rho_{s_{ind}} = \frac{100 + \text{Column14}}{100} \times \text{Column5}$$

Table A-2

			At base conditions		At sample gas conditions of °C and bars									
1 Gas type	2 Molecular mass M[1]	3 γ at sample conditions [2]	4 Z_s [3]	5 ρ_s^{true} [4]	6 V_F [5]	7 Z[6]	8 Z_F [7]	9 E_F [8]	10 Δ_F% [9]	11 E_1 [10]	12 Δ_1% [11]	13 E_2 [12]	14 Δ_2% [13]	15 $\rho_s^{ind.}$ [14]
Cal	16.04	1.32	0.9977	X 0.7171	0.9916	0.987 6	0.9899	x 0.9816	0	x 0.9816	0	x 0.9816	0	X 0.7171
Cal	28.01	1.41	0.9995	Y 1.2500	0.9862	0.998 3	0.9988	y 0.9850	0	y 0.9850	0	E_{2y} 0.9712	–1.38	Y' 1.2328
Sample	16.96	1.32	0.9976	A 0.7583	0.9911	0.987 1	0.9895	a 0.9807	0.13	E_{1a} 0.9820	0.13	E_{2a} 0.9803	–0.04	A' 0.7580
Sample	17.32	1.32	0.9977	B 0.7743	0.9909	0.987 3	0.9896	b 0.9806	0.16	E_{1b} 0.9822	0.16	E_{2b} 0.9798	–0.08	B' 0.7737
Sample	19.28	1.30	0.9972	C 0.8624	0.9897	0.984 9	0.9877	c 0.9775	2.25	E_{1c} 0.9829	0.54	0.9775	0	C' 0.8624

(1) Column 2 data derived from page x.x or other suitable tables.
(2) Column 3 data is interpolated from International Standard Gas Tables (for example, IUPAC) at SAMPLE GAS conditions.
(3) Column 4 data is interpolated from International Standard Gas Tables (for example, IUPAC) at BASE GAS conditions.
(4) Column 5 data calculated using:

$$\rho_s = \frac{P_s M}{0.0831434 \times T_s \times Z_s}$$

(5) Column 6 data calculated using:

$$V_F = 1 - \frac{M}{\gamma} \times 0.000695$$

(6) Column 7 data calculated using Z = 1–0.000238P for Nitrogen; Z = 1+P(0.00017+6E–05M x 1.13E–05M^2+7.2E–03 x I) for CH_4, where P is pressure in bars absolute and I is volume/mole fraction of inert gases.
(7) Column 8 data calculated using Z_F = Column 7/Column 4.
(8) Column 9 data calculated usig E_F = Column 6 x Column 8.
(9) Column 10 data calculated using Δ_F% = (1–Column 9) x 100%.
(10) Column 11 data is E_1 = x or y, or calculated for E_{1a}, E_{1b}, or E_{1c} (see A10 on page 52).
(11) Column 12 data calculated using Δ_1% = (Column 11–Column 9) x 100%.
(12) Column 13 data is E_2 = x or c, or calculated for E_{2a}, E_{2b}, or E_{2c} (see A11 on page 52).
(13) Column 14 data calculated using Δ_2% = (Column 13–Column 9) x 100%
(14) Column 15 data calculated using:

$$\rho_{s_{ind}} = \frac{100 + \text{Column14}}{100} \times \text{Column5}$$

Example Calculations

Column 5	Methane	$\frac{1x16.04}{0.0831434x273.155x0.9977} = 0.7171$
	Nitrogen	$\frac{1x28.01}{0.0831434x273.155x0.9995} = 1.250$
	Sample A	$\frac{1x16.96}{0.0831434x273.155x0.9976} = 0.7583$
	Sample B	$\frac{1x17.32}{0.0831434x273.155x0.9977} = 0.7743$
	Sample C	$\frac{1x19.28}{0.0831434x273.155x0.9972} = 0.8624$

Column 6	Methane	$1 - \frac{16.04}{1.32} x0.000695 = 0.9916$
	Nitrogen	$1 - \frac{28.01}{1.41} x0.000695 = 0.9862$
	Sample A	$1 - \frac{16.96}{1.32} x0.000695 = 0.9911$
	Sample B	$1 - \frac{17.32}{1.32} x0.000695 = 0.9909$
	Sample C	$1 - \frac{19.28}{1.30} x0.000695 = 0.9897$

Column 7	Methane	= 1+7(0.00017+6E–5x16.04–1.13E–5x16.04^2+0) = 0.9876
	Nitrogen	1 – 0.000238 x 7 = 0.9983
	Sample A	1+7(0.00017+6E–5x16.96–1.13E–5x16.96^2+0.0072x0.03) = 0.9871 (I=0.03)
	Sample B	= 1+7(0.00017+6E–5x17.32–1.13E–5x17.32^2+0.0072x0.05) = 0.9873(I= 0.05)
	Sample C	= 1+7(0.00017+6E–5x19.28–1.13E–5x19.28^2+0.0072x0.1) = 0.9849 (I=0.1)

Column 8	Methane	$\frac{0.9876}{0.9977} = 0.9899$
	Nitrogen	$\frac{0.9983}{0.9995} = 0.9988$
	Sample A	$\frac{0.9871}{0.9976} = 0.9895$
	Sample B	$\frac{0.9873}{0.9977} = 0.9896$
	Sample C	$\frac{0.9849}{0.9972} = 0.9877$

Column 9	Methane	= 0.9816
	Nitrogen	= 0.9850
	Sample A	= 0.9807
	Sample B	= 0.9806
	Sample C	= 0.9775

Column 10	Methane	1.84
	Nitrogen	1.50
	Sample A	1.93
	Sample B	1.94
	Sample C	2.25

Column 11	Methane	= 0.9816
	Nitrogen	= 0.9850
	Sample A	$1-\frac{0.7171(1-0.9816)}{0.7583}-\frac{(0.7583-0.7171)[1.25(1-0.985)-0.7171(1-0.9816)]}{0.7583(1.25-0.7171)}$ = 0.982
	Sample B	= 0.9822 $1-\frac{0.7171(1-0.9816)}{0.7743}-\frac{(0.7743-0.7171)[1.25(1-0.985)-0.7171(1-0.9816)]}{0.7743(1.25-0.7171)}$
	Sample C	$1-\frac{0.7171(1-0.9816)}{0.8624}-\frac{(0.8624-0.7171)[1.25(1-0.985)-0.7171(1-0.9816)]}{0.8624(1.25-0.7171)}$ = 0.9829

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Column 12	Methane	0
	Nitrogen	0
	Sample A	0.13
	Sample B	0.16
	Sample C	0.54

Column 13	Methane	= 0.9816	
	Nitrogen	$1 - \frac{0.7171(1 - 0.9816}{1.25} - \frac{(1.25 - 0.7171)[0.8624(1 - 0.9775) - 0.7171(1 - 0.9816)]}{1.25(0.8624 - 0.7171)}$	= 0.9712
	Sample A	$1 - \frac{0.7171(1 - 0.9816}{0.7583} - \frac{(0.7583 - 0.7171)[0.8624(1 - 0.9775) - 0.7171(1 - 0.9816)]}{0.7583(0.8624 - 0.7171)}$	= 0.9803
	Sample B	$1 - \frac{0.7171(1 - 0.9816}{0.7743} - \frac{(0.7743 - 0.7171)[0.8624(1 - 0.9775) - 0.7171(1 - 0.9816)]}{0.7743(0.8624 - 0.7171)}$	= 0.9798
	Sample C	0.9775	

Column 14	Methane	0
	Nitrogen	1.38
	Sample A	–0.04
	Sample B	–0.08
	Sample C	0

Column 15	Methane	0.7171
	Nitrogen	1.2328
	Sample A	0.7580
	Sample B	0.7737
	Sample C	0.8624

An alternative method for deriving modified values of Y to produce nil error is given on the next page.

Alternative simplified method of deriving modified values of Y (the nitrogen SG value used for calibration) to produce a nil error condition for a Methane/Gas C (or Gas B or Gas A) calibration.

$$Y^{''''} = X + \frac{\left(\frac{Y}{y} - \frac{X}{x}\right)}{\left(\frac{C}{c} - \frac{X}{x}\right)} \times (C - X)$$

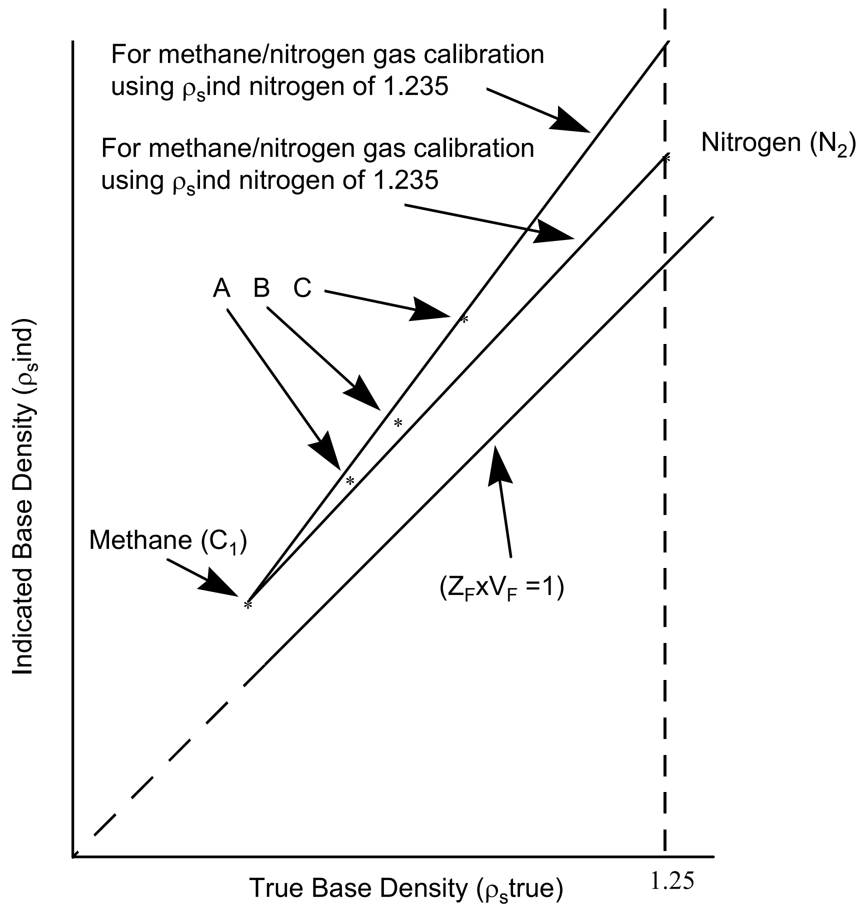
For gases A or B, substute for C and C in this equation, where:

- X,Y, C = true base densities of the gases
- x, y, c = total factors E_F

For example:

$$Y^{''''} = 0.7171 + \frac{\left(\frac{1.25}{0.985} - \frac{0.7171}{0.9816}\right)}{\left(\frac{0.8624}{0.9775} - \frac{0.7171}{0.9816}\right)} \times (0.8624 - 0.7171) = 1.2328$$

Figure A-1 Illustration of example condition



Appendix B
Principles of Operation

B.1 Theory of specific gravity measurement

By definition:

	Gas specific gravity	= Molecular weight of gas/Molecular weight of standard air
(1)	for example,	$G = M_G/M_A$
		where M_A is taken as 28.96469
	Relative density	= Density of gas/Density of air
(2)	for example,	$\rho_r = \rho_G/\rho_A$
		at the same conditions of temperature and pressure.

The relative density is numerically equal to specific gravity when the supercompressibility factors of both the gas and the standard air at the measurement conditions are taken into consideration.

Therefore:

(3)

$$G = \frac{\rho_G Z_G}{\rho_A Z_A}$$

Now let the density of the gas sample measured be ρ_1, again by definition:

(4)

$$\rho_1 = \frac{P_1 M_1}{Z_1 R T_1}$$

By comparing the density of the sample gas with the density of a fixed quantity of a reference gas contained in a fixed volume:

(5) where

$$\rho_2 = \frac{P_2 M_2}{Z_2 R T_2}$$

Since conditions of constant volume and quantity exist for the reference gas, its density and molecular weight are constant and from equation 5.

(6)

$$\frac{\rho_2}{M_2} = \frac{P_2}{Z_2RT_2} = K$$

If now the two gases can be maintained at the same temperature, from equations 4 and 6:

(7)

$$\rho_1 = \frac{P_2M_1}{Z_1RT_2} = KM_1\frac{Z_2}{Z_1}$$

Finally, by using the sample gas (or a gas having a similar supercompressibility factor) as the reference gas:

(8)

$$\rho_1 = KM_1$$

since $Z_1 = Z_2$

Thus the density of the sample gas, under the stated conditions, is directly related to its molecular weight and therefore directly related to its specific gravity by equation 1.

Appendix C
Return Policy

C.1 General guidelines

Micro Motion procedures must be followed when returning equipment. These procedures ensure legal compliance with government transportation agencies and help provide a safe working environment for Micro Motion employees. Failure to follow Micro Motion procedures will result in your equipment being refused delivery.

Information on return procedures and forms is available on our web support system at **www.micromotion.com**, or by phoning the Micro Motion Customer Service department.

C.2 New and unused equipment

Only equipment that has not been removed from the original shipping package will be considered new and unused. New and unused equipment requires a completed Return Materials Authorization form.

C.3 Used equipment

All equipment that is not classified as new and unused is considered used. This equipment must be completely decontaminated and cleaned before being returned.

Used equipment must be accompanied by a completed Return Materials Authorization form and a Decontamination Statement for all process fluids that have been in contact with the equipment. If a Decontamination Statement cannot be completed (for example, for food-grade process fluids), you must include a statement certifying decontamination and documenting all foreign substances that have come in contact with the equipment.

Appendix D
Certified System Drawings

D.1 General

All certified drawings in this manual are given here for planning purposes only. Before commencing with implementation, reference should always be made to the current issue of the certified drawings. Contact the factory for further details.

No.	Drawing reference	Description
1	78125039A Sheet 1 of 4	CSA system drawing, gas groups A, B, C, and D (2-wire option) shunt diode barrier
	78125039A Sheet 2 of 4	CSA system drawing, gas groups A, B, C, and D (3-wire option) shunt diode barrier
	78125039A Sheet 3 of 4	CSA system drawing, gas groups A, B, C, and D (2-wire option) isolated interface units
	78125039A Sheet 4 of 4	CSA system drawing, gas groups A, B, C, and D (3-wire option) isolated interface units

Figure D-1 CSA system drawing, gas groups A, B, C, and D (2-wire option) shunt diode barrier

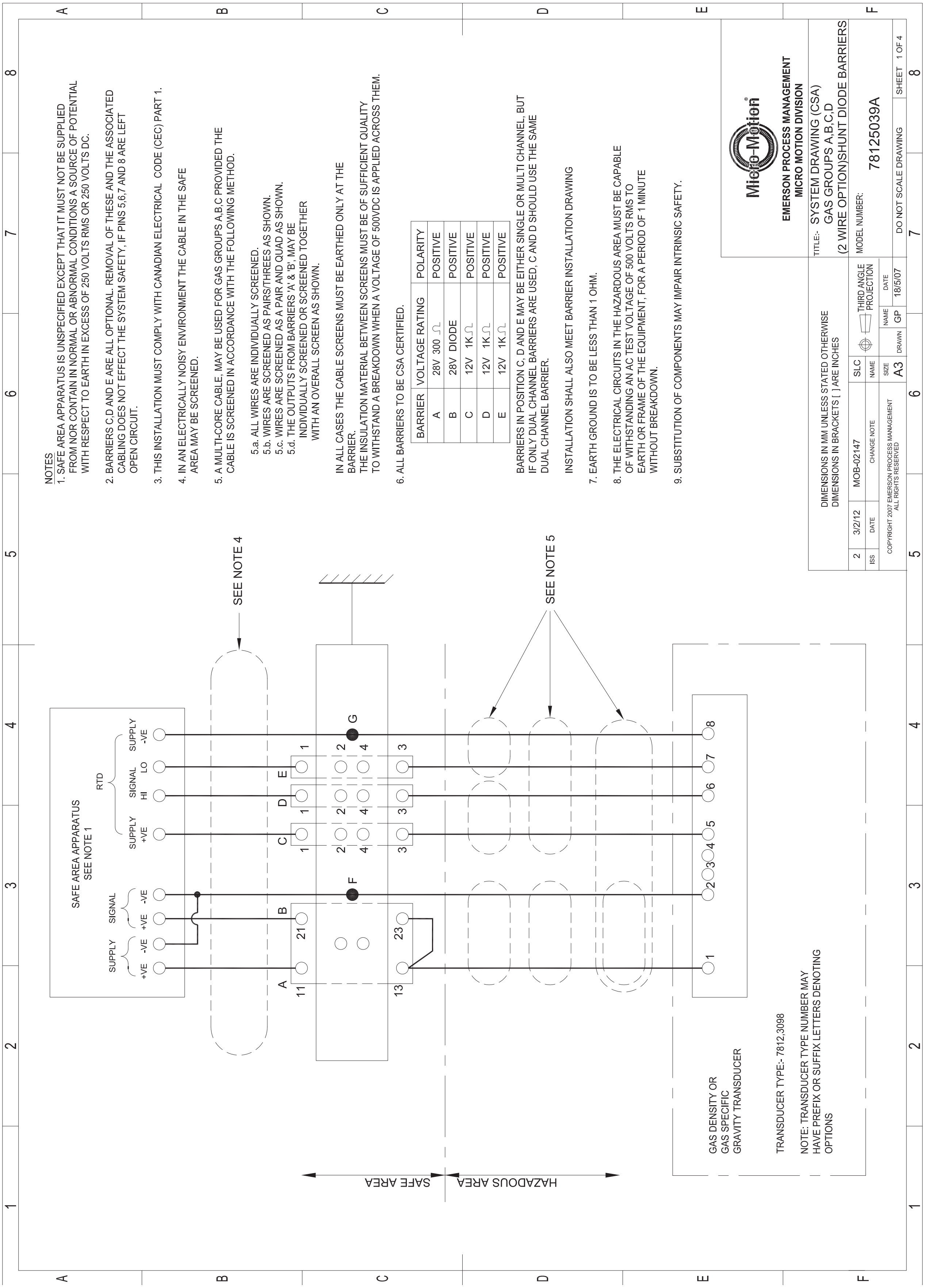


Figure D-2 CSA system drawing, gas groups A, B, C, and D (3-wire option) shunt diode barrier

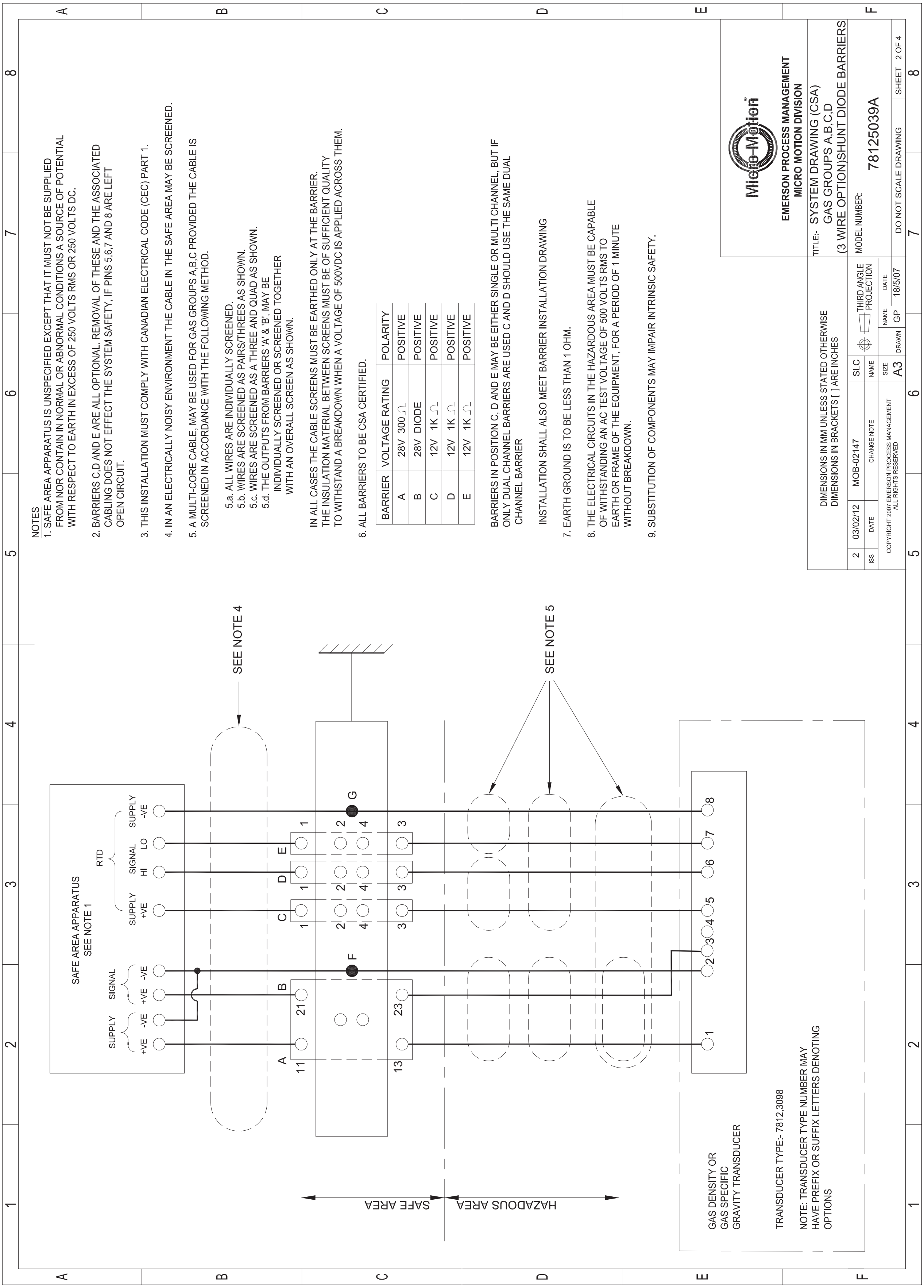


Figure D-3 CSA system drawing, gas groups A, B, C, and D (2-wire option) isolating interface units

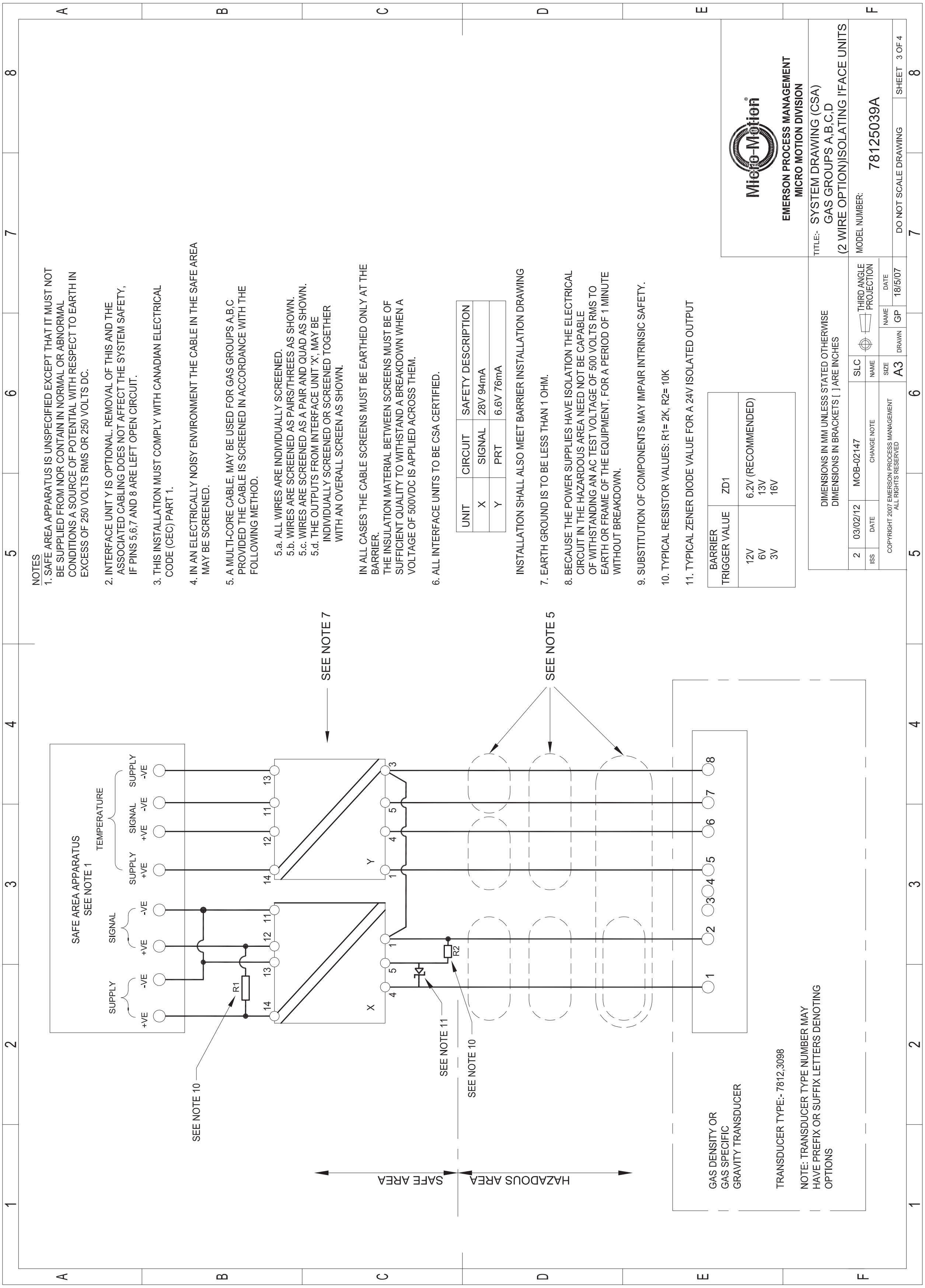
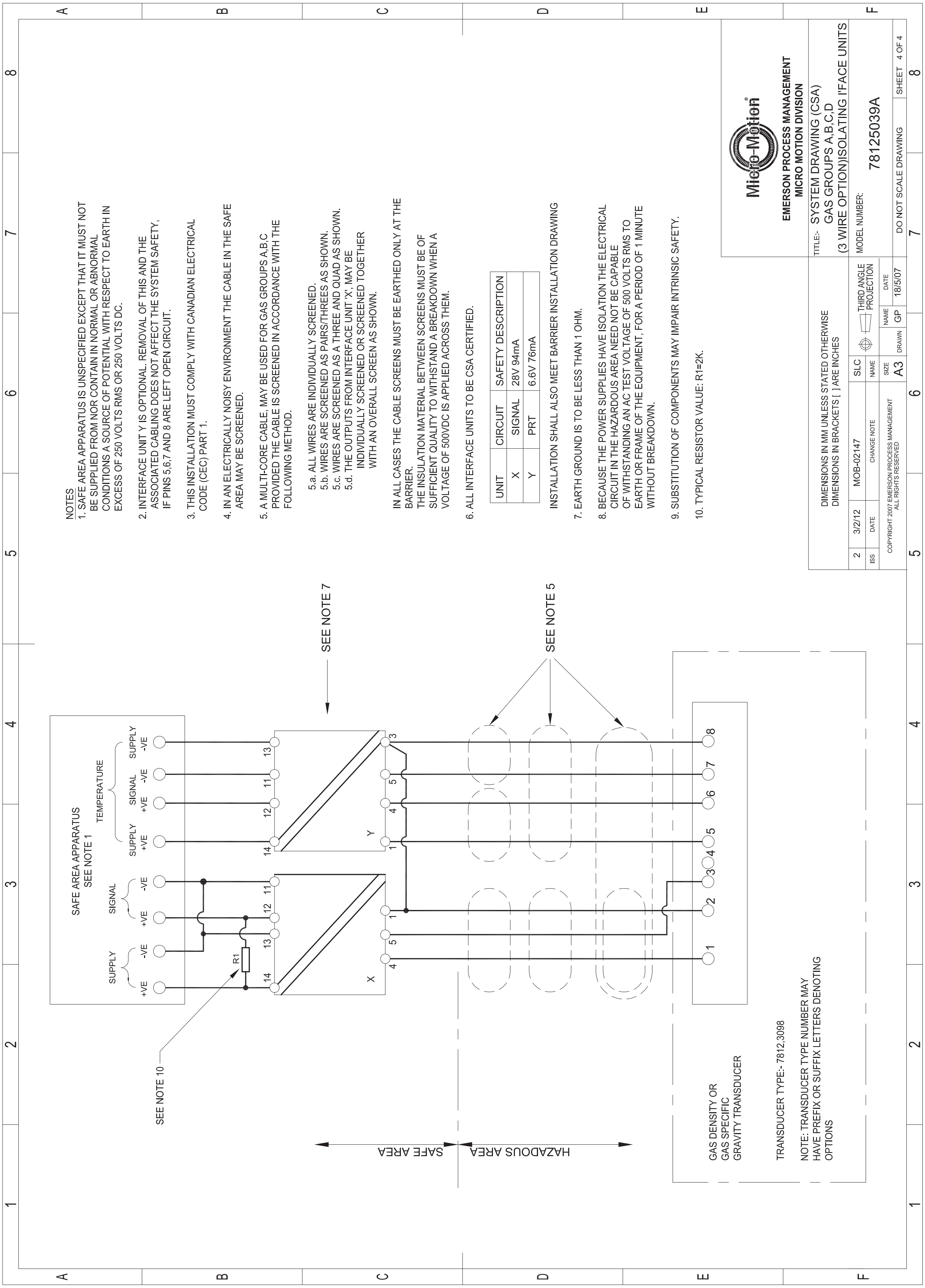


Figure D-4 CSA system drawing, gas groups A, B, C, and D (3-wire option) isolating interface units



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